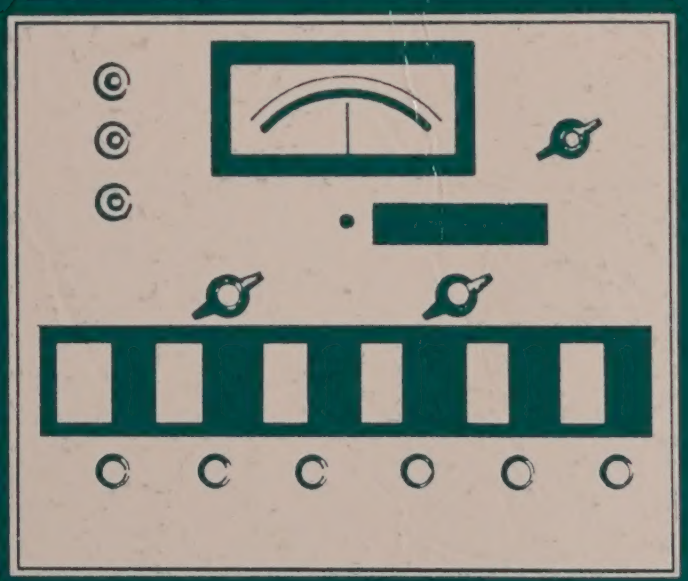
Service Seminar



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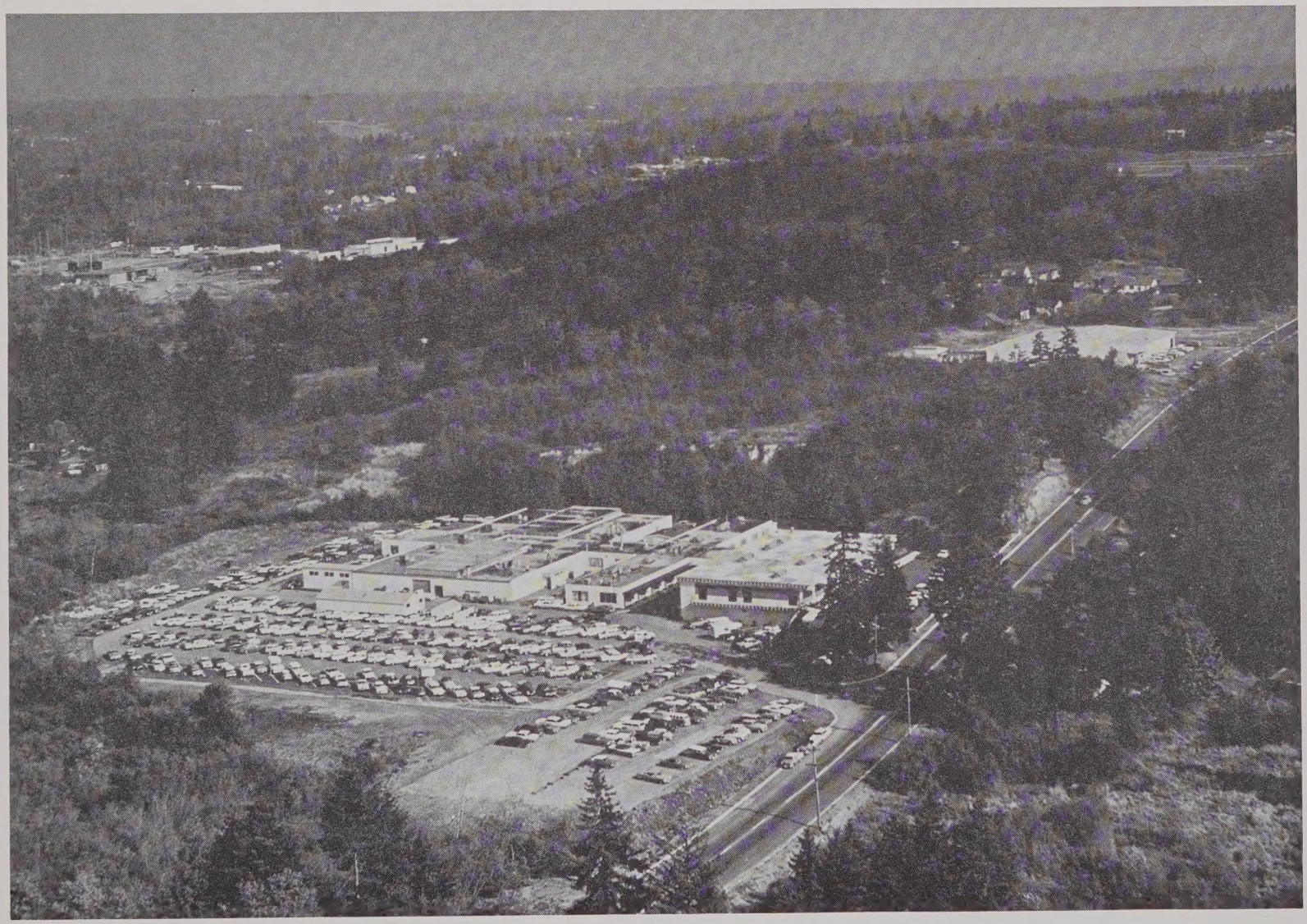
FLUKE

SERVICE SEMINAR

JOHN FLUKE MFG. CO., INC.
P.O. Box 7428 Seattle, Washington 98133



JOHN FLUKE MFG. CO., INC.

PHILOSOPHY OF MAINTENANCE AND CALIBRATION OF ELECTRONIC INSTRUMENTATION

OBJECTIVES

There are two primary objectives that should be foremost in the minds of those who are charged with the responsibility of maintaining and calibrating electronic instrumentation. They are, (1) to insure that all of the instruments are within the manufacturer's specifications at all times, and (2) to provide the above assurance at the least possible cost.

IMPLEMENTATION OF OBJECTIVES

The first step in carrying out the above objectives is to establish an arbitrary calibration cycle for each item of equipment as it is added to the jurisdiction of the calibration facility. This cycle is determined by a recommendation from the manufacturer, from the specification of the instrument relative to long-term stability, or from prior experience with the type of instrument involved.

Since it won't be until the first recalibration cycle that initially established guidelines become important, that will be the point in time to begin regarding the instrument critically from a historical viewpoint.

When an instrument returns to the calibration facility for its first recalibration, there are certain checks that should be made and recorded in order to establish a reference for later judgement. These checks come under the heading of VERIFICATION OF ACCURACY AND GENERAL PERFORMANCE, and can be set down for any item of equipment. An example of this would be as follows:

Fluke Differential Voltmeter - (Older tube type)

1. Apply full-scale DC source voltages for all ranges. Null the applied voltage and record the reading made by the instrument.

2. Null out an applied voltage that represents the centerpoint of the Kelvin-Varley on the lowest voltage range of the instrument. (In this case, 0.25555V).

3. Apply, and null, AC voltages (on applicable units) at two frequencies (400 Hz and 5 kHz) on all full-scale ranges. In addition, make one reading at 5 kHz at one-tenth full-scale of the lowest AC range.

The foregoing checks on this instrument were based on its front panel controls, and what would represent some "worst case" conditions insofar as its specifications are concerned. The same can be done for any unit to provide a quick profile of its operational capability. And of course the readings taken can be directly compared to instrument accuracy so that a reliability figure can be established.

At the same time that these initial readings are taken, the general performance of the instrument can be noted. In other words, such items as switch action, meter action, and physical appearance should be checked and noted for any deficiencies so that they are sure to be taken care of during the instrument's precalibration.

NOTE: If any one of the measurements made on the unit is out of manufacturer's specifications, the instrument should be labeled as "DEFECTIVE UPON RECEIPT".

This statement will be used for determining the historical reliability of that type of instrument.

Having obtained the necessary information from the preliminary checks, the unit is now available to be processed thru the normal channels of PRECALIBRATION and FINAL CALIBRATION prior to returning it to the using agency. The manipulation of the instrument thru these processes is recommended as follows:

PRECALIBRATION

1. Process the instrument thru a complete hygine program that will purge it of environmental contamination. Areas of particular concern are the switches which can account for many cases of instrument inaccuracy. This can contribute to such problems as leakage, hi-voltage arc-over, or hi resistance contacts to low impedance circuitry. The hygiene program suggested for all electronic instrumentation is a water-detergent spray cleaner followed by oven drying (see brochure in the back of this booklet).

2. This is an opportune time to apply any updating modifications to the instrument that will improve its performance.

3. A parameter check of all of the block sections is the next step. This will insure that each and every portion of the instrument is placed in peak operating condition so that it will contribute the least possible amount toward overall instrument inaccuracy. In conjunction with the checkout of the various auxiliary sections may come the need for component replacement. As each malfunction is corrected, a complete recheck of that particular section is in order.

CALIBRATION

Now that the instrument is completely operable in every respect, and has reached its normal operating temperature, the final calibration of the instrument as a whole can be performed. It is well to assume during this final calibration that NONE of the calibration points are at their proper setting. The routine of calibration should be to deliberately rotate a calibration adjustment away from its present set point so as to make it mandatory that the final setting is optimized relative to the source devices by the person doing the calibration. An added bonus to this approach is that the deliberate rotation (back and forth several times, in fact) will help eradicate a buildup of corrosion that is usually present.

Note that at this point in the processing of any instrument that the reference point has been established for the perpetual historical records. The next time that the instrument is returned from the using agency there will be an absolute check of the VERIFICATION OF ACCURACY versus the previous calibration. This comparison will be instrumental in determining the past reliability and future calibration cycle time periods.

POST-CALIBRATION

There are some instruments that require an additional check even after the FINAL CALIBRATION has been completed. Two examples of this need are: A stability check of up to seven days on a Calibration Power Supply, and a "Cold Check"* of a tube-type Differential Voltmeter. These "after calibration" checks provide at least two essential benefits.

1. If any components have been replaced during PRECALIBRATION, this provides a check that will help determine whether or not the replacement does its job as a good, stable correction to the original malfunction.

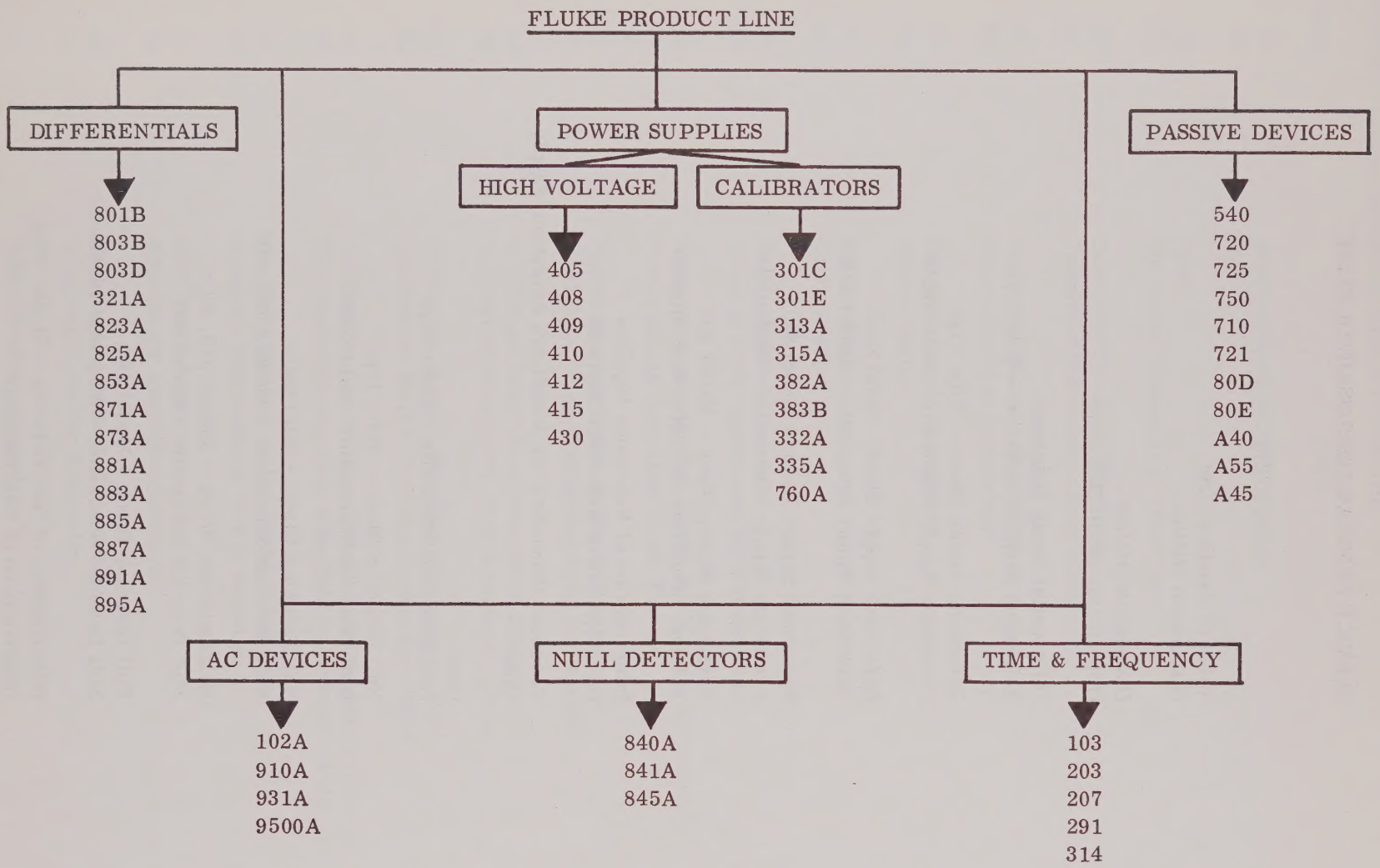
2. The performance of the post-calibration checks will also increase the odds of predicting long-term stability of the whole instrument by double-checking all components during the period of warm up.

SUMMARY

When a complete program is established in a Calibration Facility, and adhered to by performing the foregoing processes to each and every instrument the net results will be exactly what was desired by the original objectives. The long-term results will be a lessening of time spent per instrument and therefore the costs of operating a Calibration Facility. The immediate results will be the ability to intelligently extrapolate the information on hand to determine when the calibration cycle can be lengthened while still maintaining instrument accuracy and reliability.

Customer Service Department
John Fluke Manufacturing Co., Inc.

* "Cold Check" is defined as a special type of verification of accuracy check. The same source voltages are used (in this case, DC only) as were used when the instrument was first received. The difference is, that the unit is not allowed to reach its ambient temperature at the time the readings are made. If it is found that the ability of the instrument to read a voltage differs from the settings made during calibration by more than 1/3 of the manufacturer's specifications, then that instrument should undergo additional maintenance.


FLUKE PRODUCT LINE
DIFFERENTIALS
801B
803B
803D
321A
823A
825A
853A
871A
873A
881A
883A
885A
887A
891A
895A
POWER SUPPLIES
HIGH VOLTAGE
405
408
409
410
412
415
430
CALIBRATORS
301C
301E
313A
315A
382A
383B
332A
335A
760A
PASSIVE DEVICES
540
720
725
750
710
721
80D
80E
A40
A55
A45
AC DEVICES
102A
910A
931A
9500A
NULL DETECTORS
840A
841A
845A
TIME & FREQUENCY
103
203
207
291
314

SERVICE SEMINAR DISCUSSION OUTLINE

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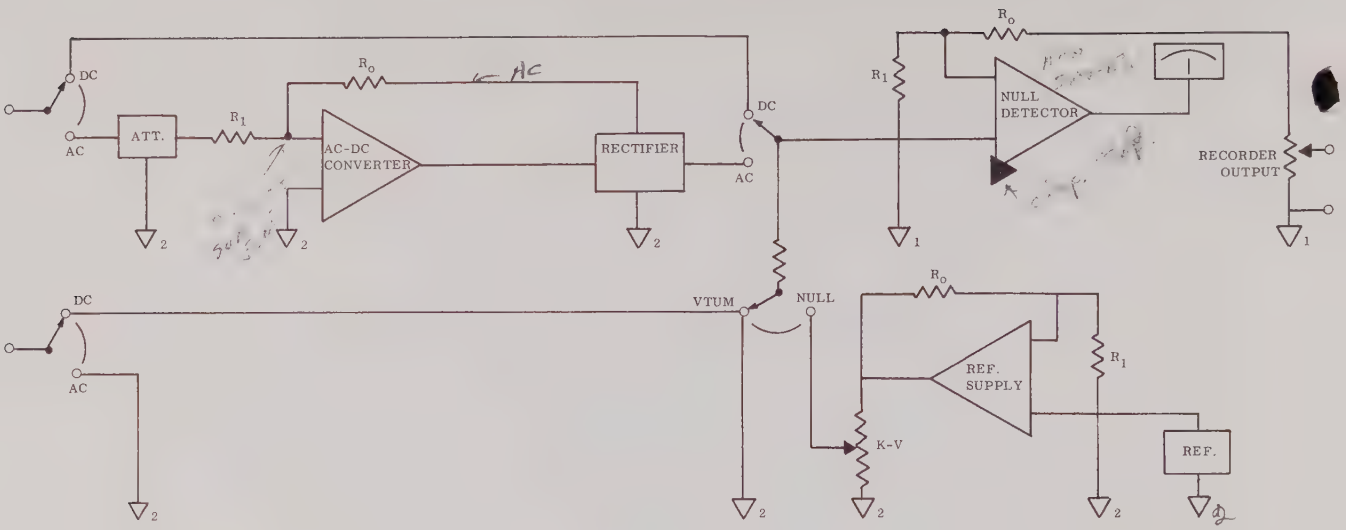
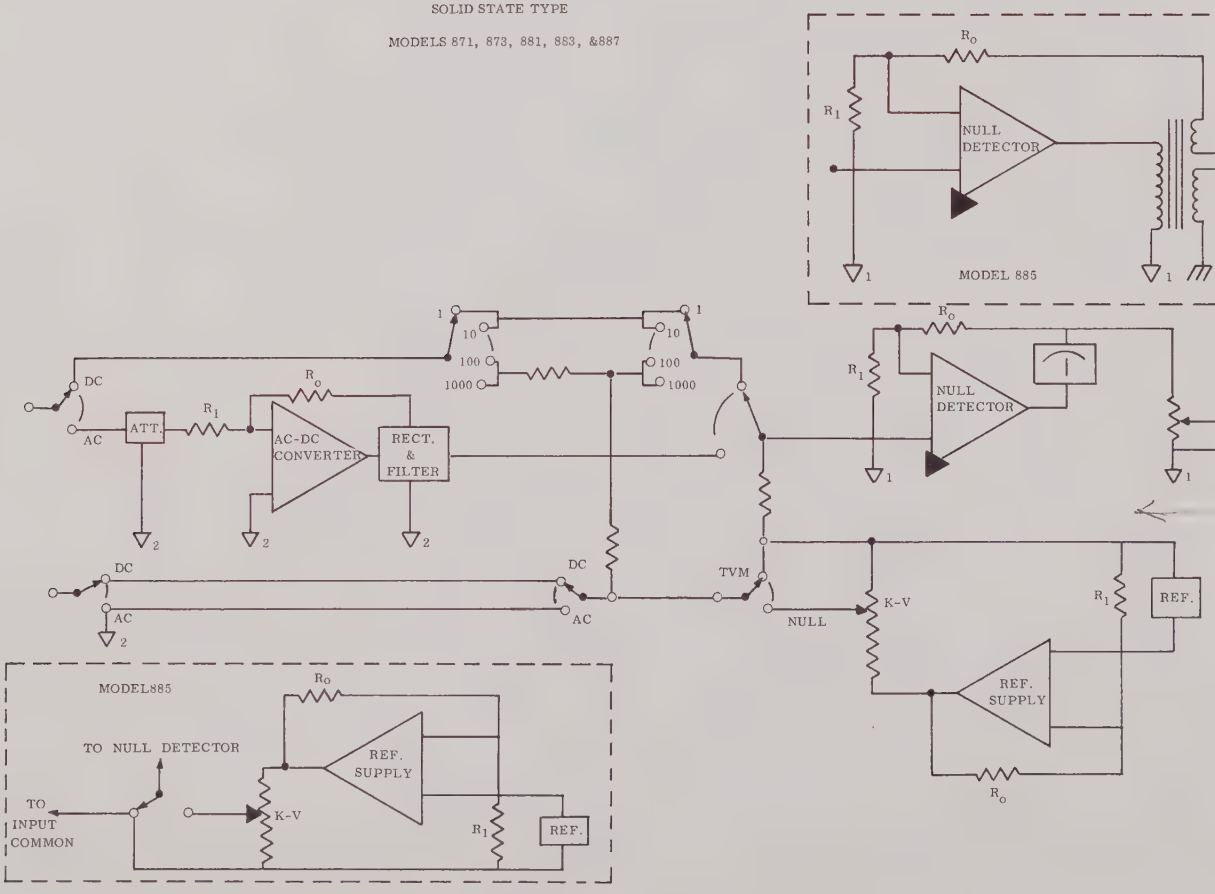
59	RMS Digit Amplifier Schematic
60	RMS Null Detector Schematic
61	RMS Checkout Procedure

DIFFERENTIAL VOLTMETER BLOCK DIAGRAMS
TUBE-TYPE

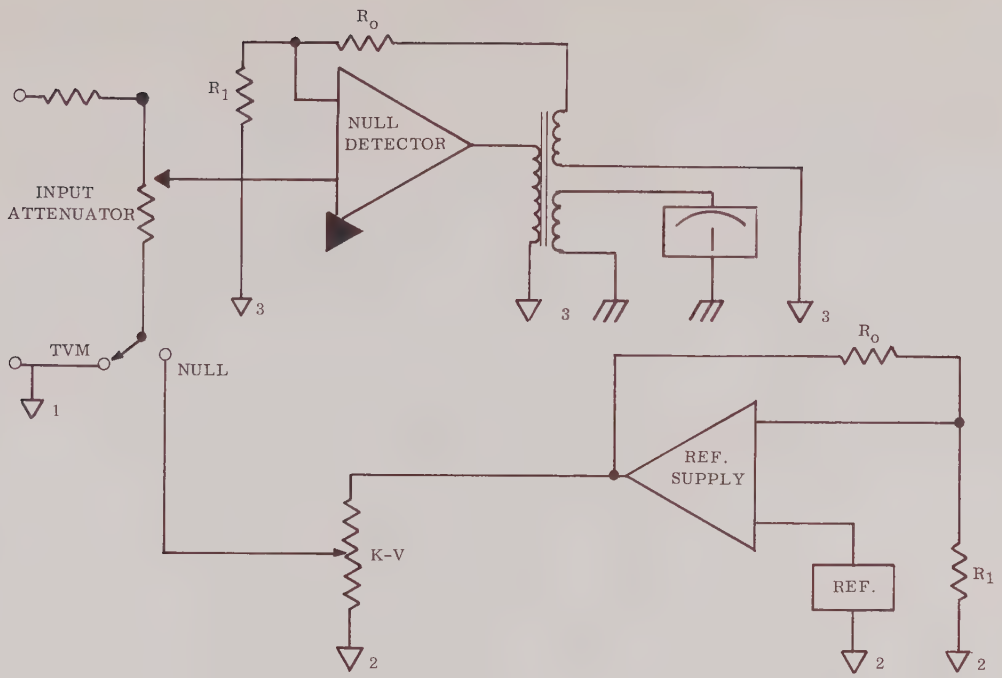


SOLID STATE TYPE

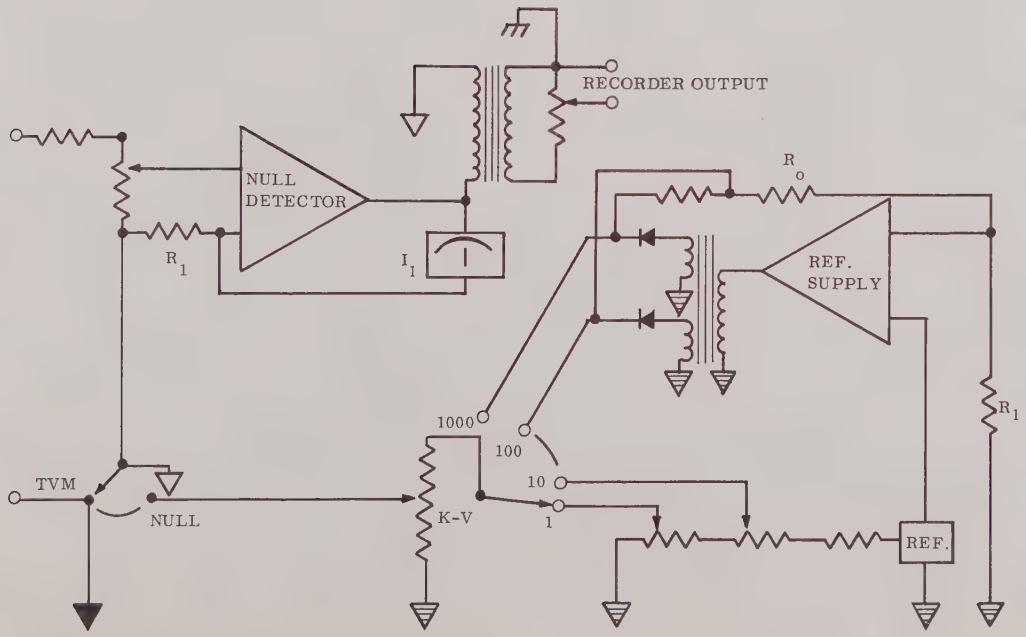
MODELS 871, 873, 881, 883, &887

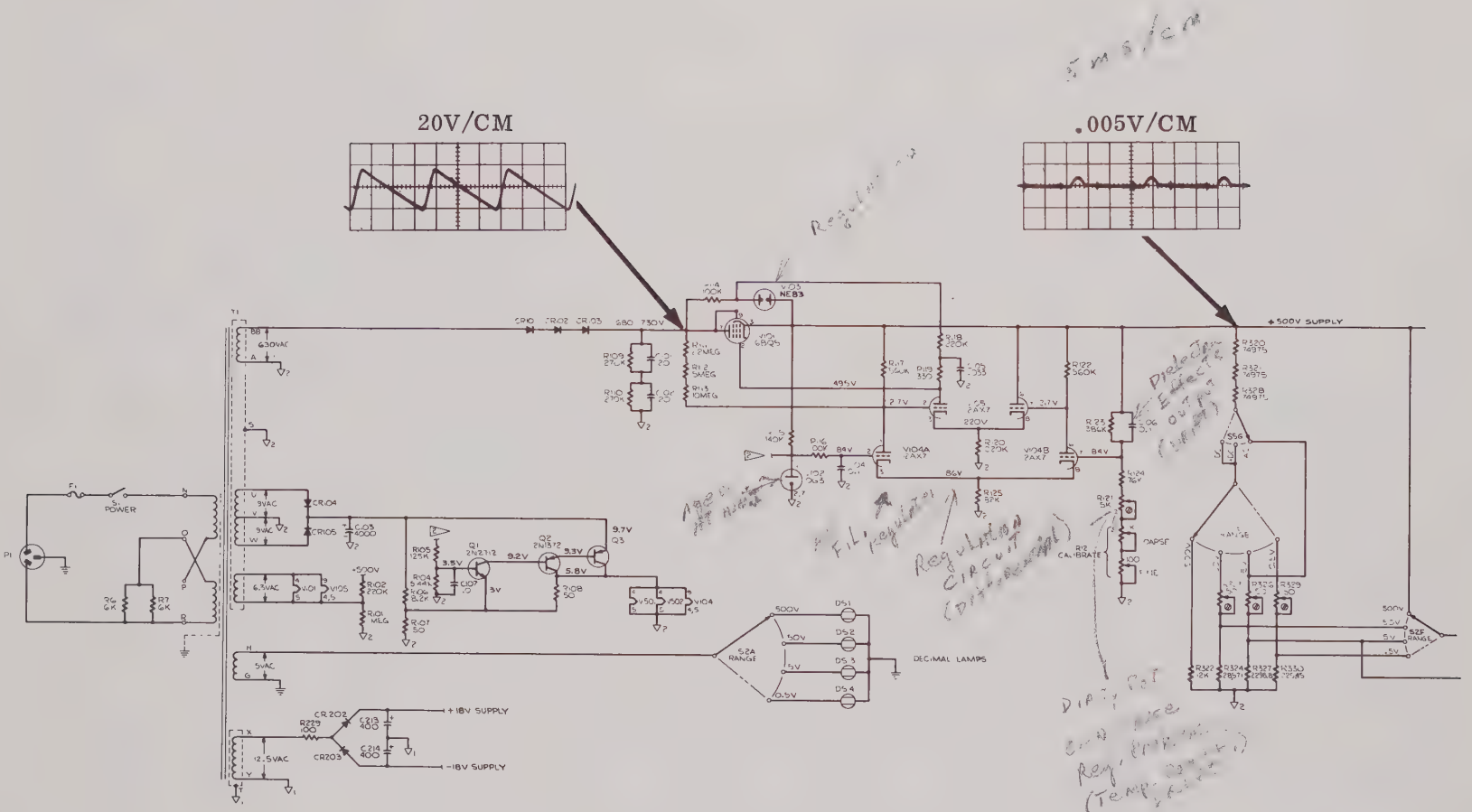


MODEL 895



MODEL 891




20V/CM
.005V/CM
+500V SUPPLY
POWER
+18V SUPPLY
-18V SUPPLY
DECIMAL LAMPS
5.2A RANGE
CR202
CR203
CR201
CR102
CR103
CR104
CR105
Q1 2N3172
Q2 2N3172
Q3
V103 NE83
V101 6BQ5
V104A 12AX7
V104B 12AX7
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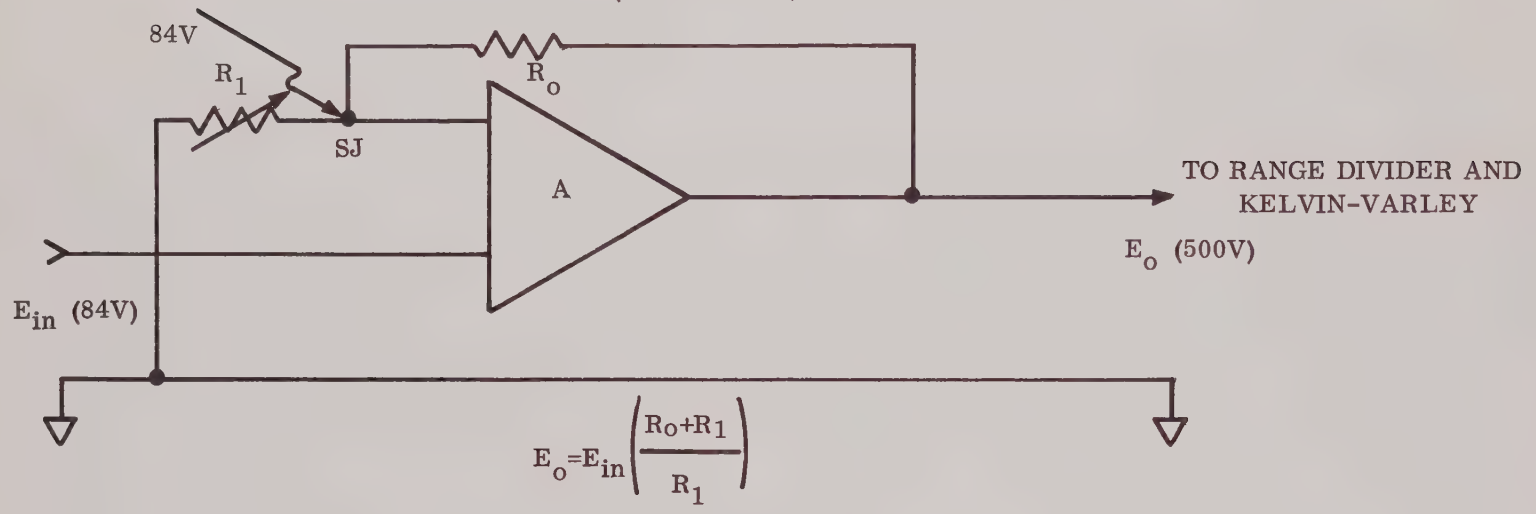
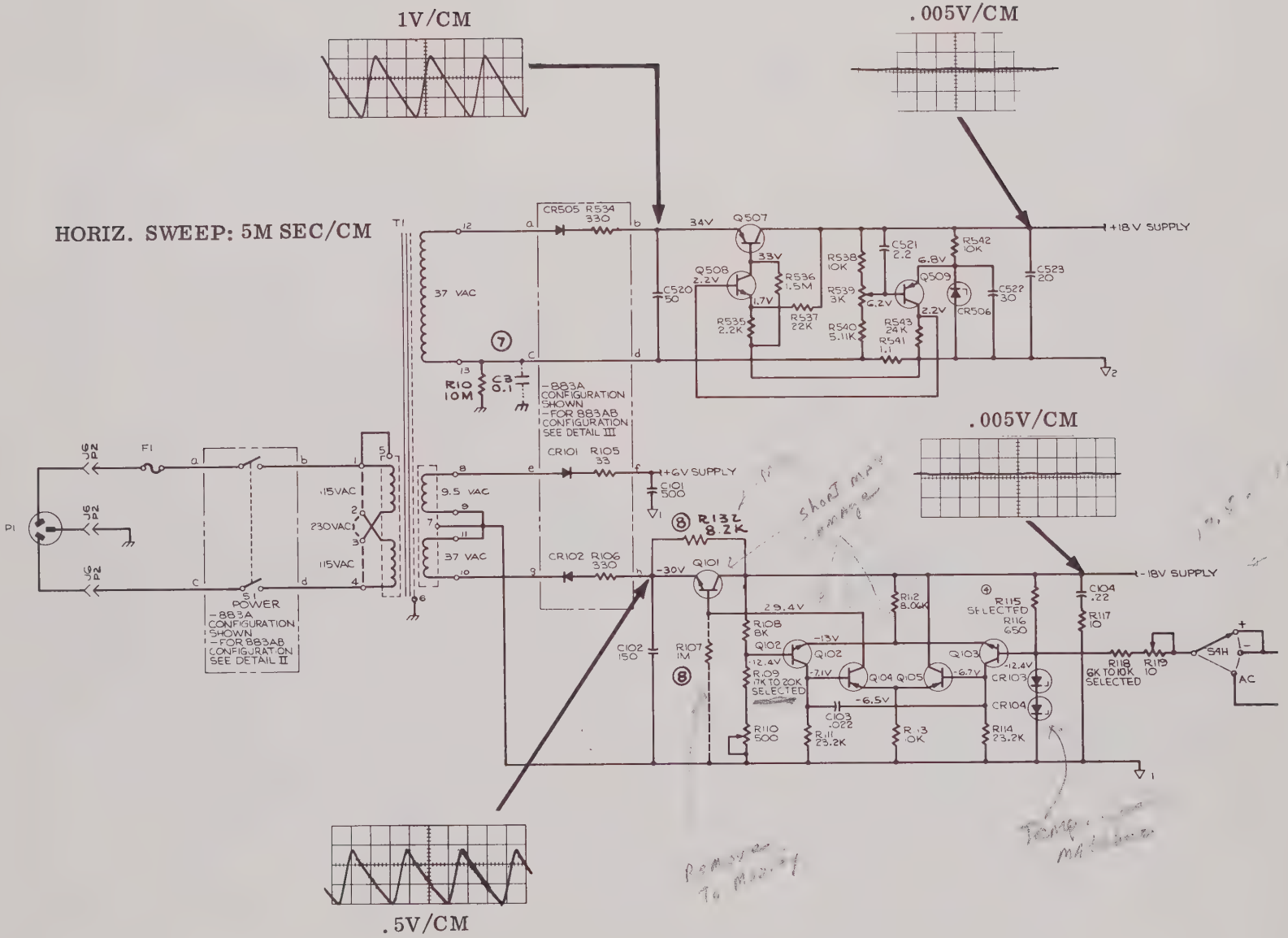
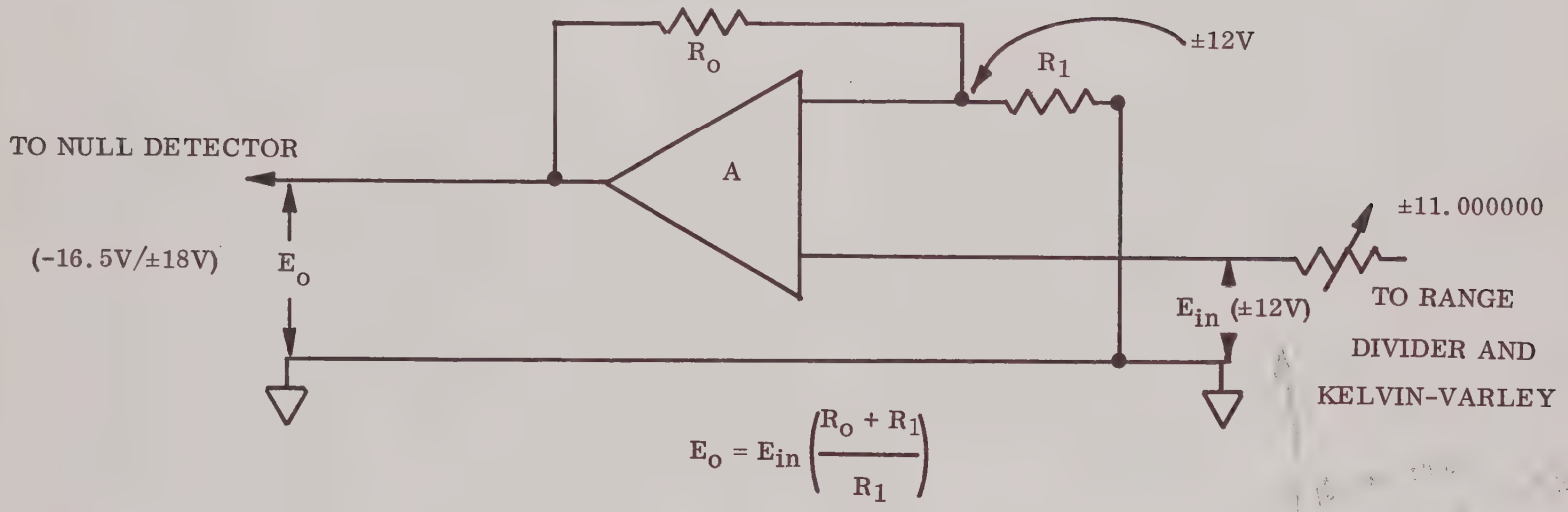
DIFFERENTIAL VOLTMETER REFERENCE SUPPLY
(TUBE-TYPE)



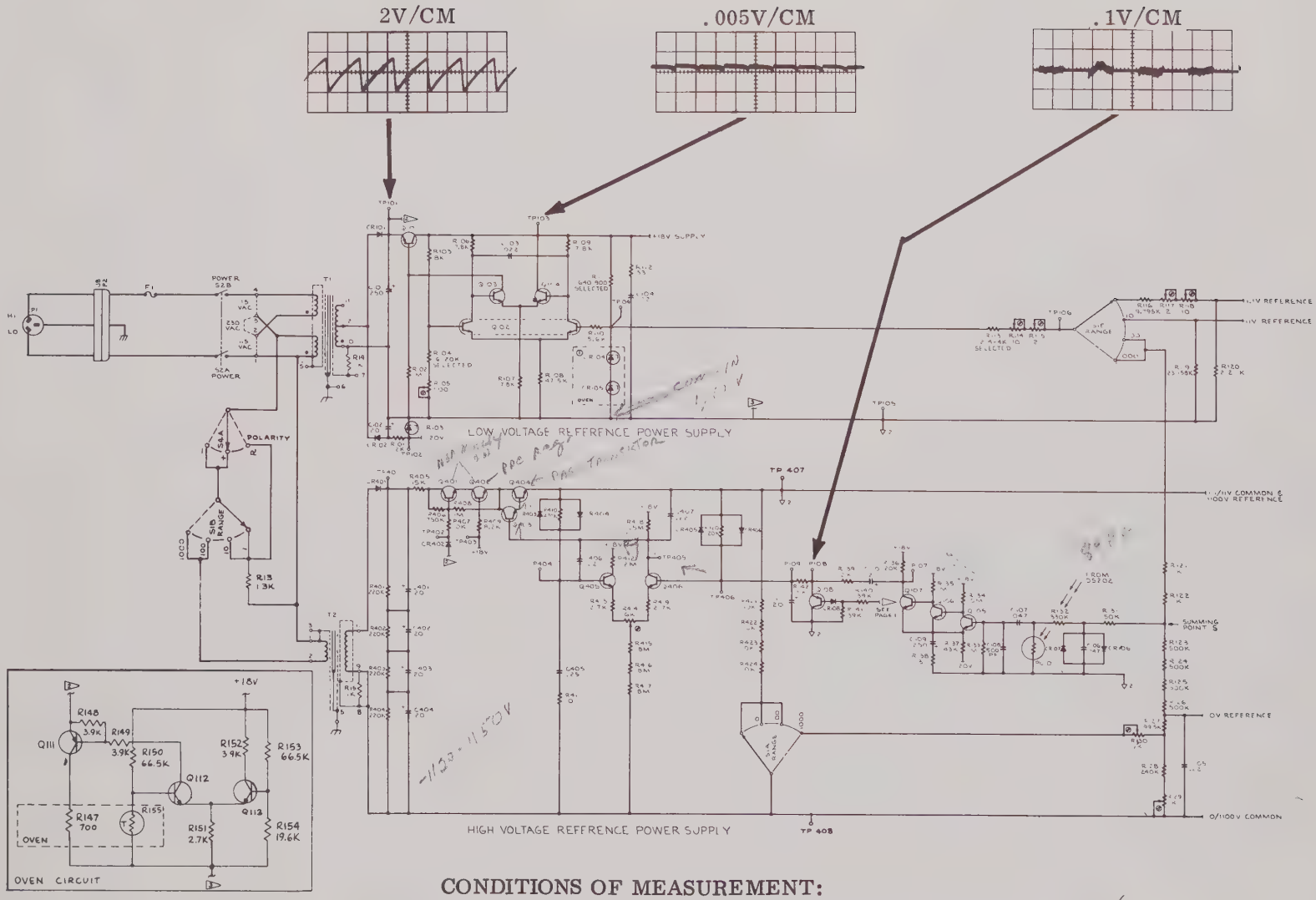
MODEL #'S	(SCHEMATIC DESIGNATIONS) E_{in}	R_1	R_o	(NOMINAL VALUES) E_{in}	R_1	R_o
801B 803B 803D 821A 823A 825A	...R2, R121, R124	R123	V102	84V	76K-82K	386K
800.....P1, P3, R18		R17	V7, V8			
801.....P1, P3, R18		R17	V7, V8	168V	158K-170K	320K
803.....R31, R32, R119		R30	V6, V7			


1V/CM
.005V/CM
HORIZ. SWEEP: 5M SEC/CM
.005V/CM
.5V/CM
+18 V SUPPLY
+6V SUPPLY
-18V SUPPLY
-30V
34V
33V
6.8V
6.2V
2.2V
1.7V
-13V
-12.4V
-7.1V
-6.7V
-6.5V
29.4V
37 VAC
9.5 VAC
37 VAC
115VAC
230VAC
115VAC
CR505 R534 330
CR101 R105 33
CR102 R106 330
R10 10M
C3 0.1
-883A CONFIGURATION SHOWN -FOR 883AB CONFIGURATION SEE DETAIL III
S1 POWER
-883A CONFIGURATION SHOWN -FOR 883AB CONFIGURATION SEE DETAIL II
Q507
Q508
Q509
Q101
Q102
Q103
Q104
Q105
CR506
CR103
CR104
C520 50
C521 2.2
C522 30
C523 20
C101 500
C102 150
C103 .022
C104 .22
R107 1M
R108 6K
R109 17K TO 20K SELECTED
R110 500
R111 23.2K
R112 8.06K
R113 10K
R114 23.2K
R115 SELECTED
R116 650
R117 10
R118 6K TO 10K SELECTED
R119 10
R132 8.2K
R535 2.2K
R536 1.5M
R537 22K
R538 10K
R539 3K
R540 5.11K
R541 1.1
R542 10K
R543 24K
S4H
AC
Remove To Mod. 91
Temp. mod

DIFFERENTIAL VOLTMETER REFERENCE SUPPLY
(SOLID-STATE)

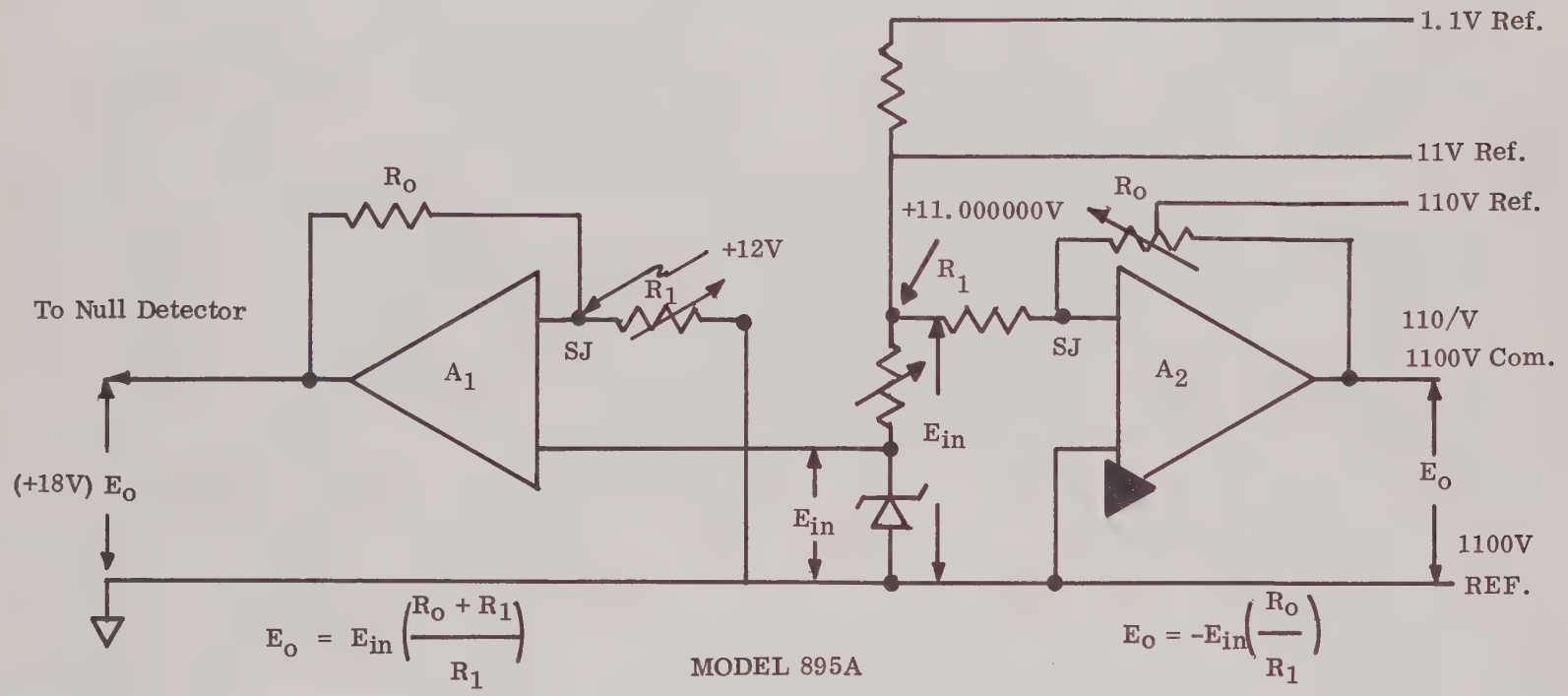


MODEL #'S	(SCHEMATIC DESIGNATION) E_{in}	R_1	R_o	(NOMINAL VALUES) E_{in}	R_1	R_o
871A	CR103, CR104	R110, R111	R109	-12V	16.2K-17.2K	4.99K
873A	CR103, CR104	R110, R111	R109	-12V	16.2K-17.2K	4.99K
881A	CR103, CR104	R109, R110	R108	-12V	17K-20K	8K
883A	CR103, CR104	R109, R110	R108	-12V	17K-20K	8K
885A	CR103, CR104	R114, R115	R113	+12V	16K-20K	8K
887A	CR103, CR104	R109, R110	R108	-12V	17K-20K	8K



CONDITIONS OF MEASUREMENT:
SCOPE: HORIZONTAL SWEEP, 5 MSEC/CM

DIFFERENTIAL VOLTMETER REFERENCE SUPPLY
(SOLID-STATE)



MODEL 895A

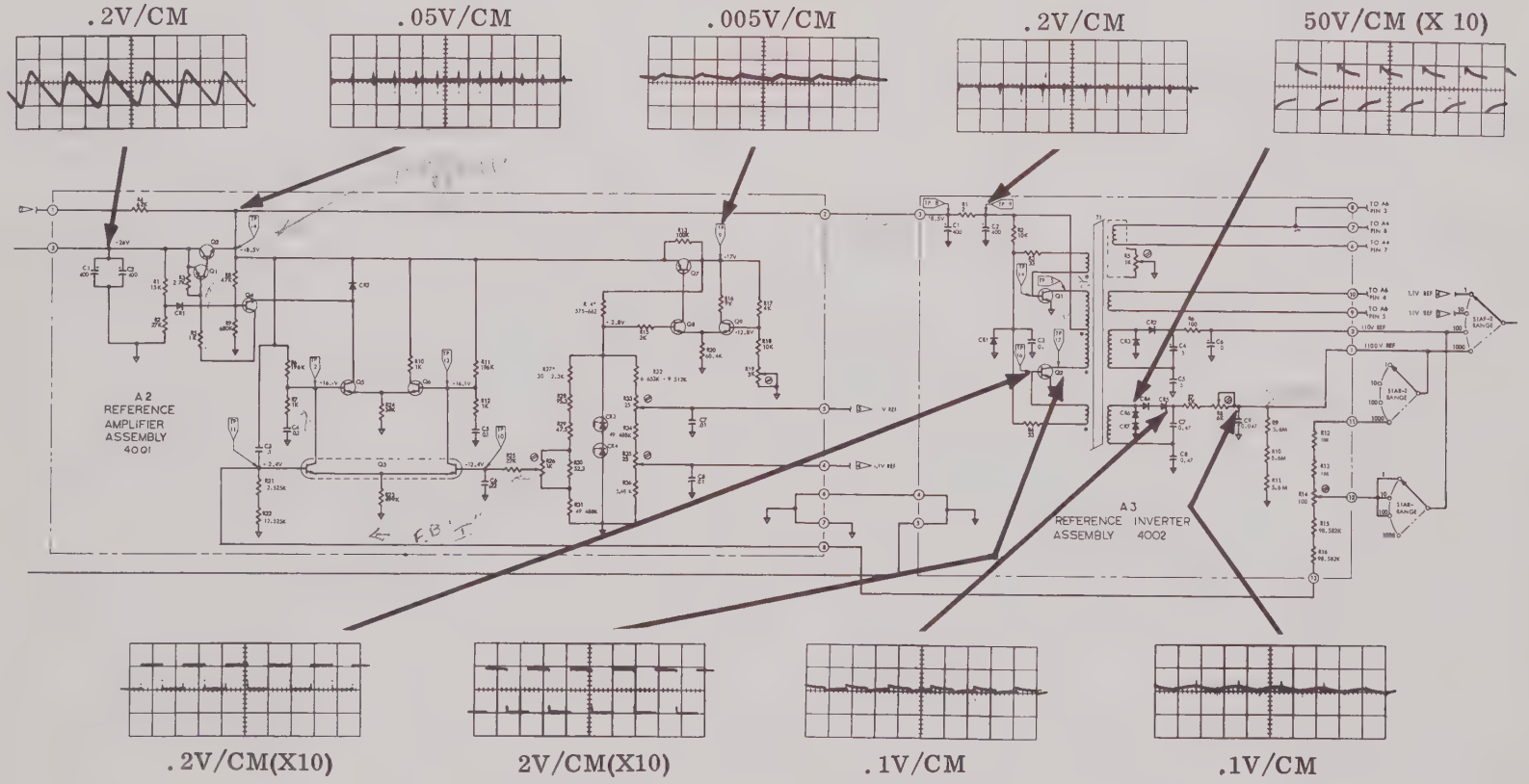
(SCHEMATIC DESIGNATION)

E_{in}	R_1	R_o
CR104, CR105	R104, R105	R103
	(nominal value)	
+12V	16K - 20K	8K

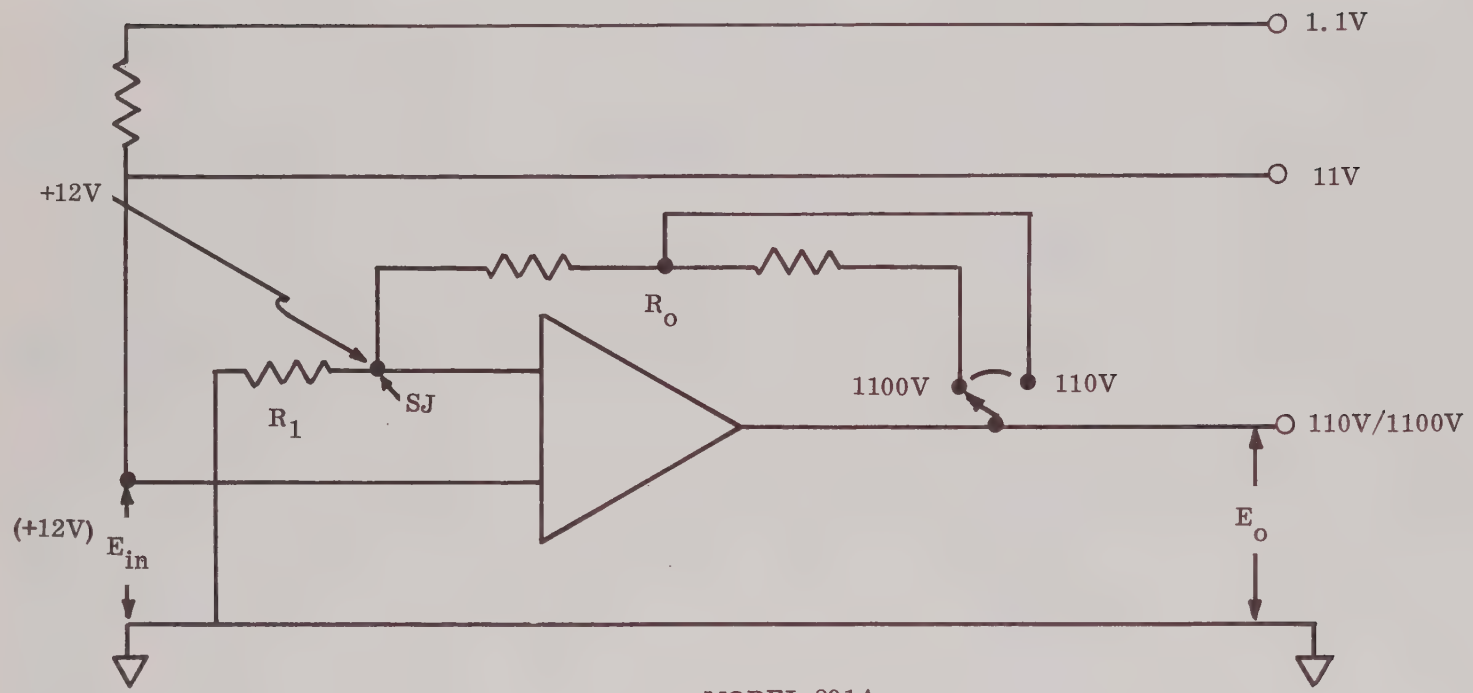
(SCHEMATIC DESIGNATION)

E_{in}	R_1	R_o
Ref. Supply	R121, R122	R123, R124 R125, R126 R127, R128 R129, R130
	(nominal value)	
+11.000000V	22K	2.2M

MEASUREMENT CONDITIONS:
HORIZONTAL SWEEP: .2 MSEC/CM
PROBE: USED WHERE (X10) IS SHOWN



DIFFERENTIAL VOLTMETER REFERENCE SUPPLY
(SOLID-STATE)



MODEL 891A

(SCHEMATIC DESIGNATION)

E_1	R_1	R_o
CR3, CR4	R21, R22	R12, R13, R14 R15, R16

(nominal values)

+12.5V	25.050K	2.222206 M

TABULATION OF TYPICAL VOLTAGES
FOR
DIFFERENTIAL VOLTMETER REFERENCE SUPPLIES

PARAMETER	TUBE-TYPE	X-ISTR THRU MODEL 887	MODEL 885	MODEL 895	MODEL 891
Raw DC to Series Pass Element:					
Line Operate	700v ±30v	-35v ±3v	35v ±3v	1560v ±20v	26v ±3v
Bat. Operate	N/A	-27v ±1v	27v ±1v		23v ±2v
Ripple at input of Series Pass Element (Line Operate only)	11v ±4v RMS	350 mv ±35 mv RMS	350 mv ±35 mv	4v ±1v	80 mv ±20 mv
Output Voltage and Adjustability	500v ± 15v	(871, 873) -16.5v ±.2v (881, 883, 887) -18v ±.2v	18v ±.2v	1100v ±.25v	18.55 ±.03v
Reference Voltage	85v ±3v	12.8v ±.5v	12.8v ±.5v	18v ±.1v	12.40v ±.02v
Output Ripple	200 uv ±20 uv	(871, 873) 400 uv ±25 uv (881, 883, 887) 100 uv ±20 uv	300 uv ±30 uv	400 uv ±40 uv	300 uv ±30 uv
Noise (Typical)	200 uv p-p	5 uv p-p	5 uv p-p	100 uv p-p	1 mv p-p

INTERROGATION OF REFERENCE SUPPLIES

Answers to the following questions can be obtained with a VTVM, an AC-DC Differential Voltmeter (883A, or equivalent), and a Scope.

1. What is the raw DC voltage? Is it nominal?
2. What is the output voltage of the reference supply? Is it high, low, or nominal?
3. Is the output voltage adjustable?
4. Are the operating voltages (element potentials) satisfactory?
5. Are the ripple measurements of both the raw DC and the output voltage o.k. ?
6. What is the magnitude of the reference voltage?
7. What is the Summing Junction voltage? Is it equal to the reference voltage?

If the answers to the above questions are completely satisfactory, the reference supply can be considered wholly operable, and will respond to calibration. Yet to be answered, however, are questions relating to other parameters of these supplies such as noise (small DC fluctuations), or drift. To interrogate the supply further it will be necessary to substitute known quantities for individual elements of the supply.

NOISE

Noise can be defined as "short term instability", and related to one or more of the following possibilities:

a) Unstable raw DC voltages
b) Unstable reference element
c) Unstable component in amplifier section
d) Erratic component in feedback network

1. Substitute an external source (332A, or equivalent) for the raw DC source. If the problem persists, remove the applied source and reconnect the instrument's own source.
2. Disconnect the reference element from the circuitry, and substitute its equivalent by the 332A. If the same noise magnitude exists, then certainly the reference element is satisfactory.
3. Disable the feedback divider from the instrument, and substitute a fixed or variable divider that has the appropriate resistance ratio. As long as this divider is known to consist of stable resistors, the instrument's own divider can be isolated as a source of the noise problem (if the noise still persists). The ratio can be quickly calculated by checking the values on the schematic, labeling the resistor from the output voltage to the Summing Junction as R_o, and the resistor from the Summing Junction to the supply common as R_1.

If all of the above checks prove to be satisfactory and do not eliminate the noise problem as a function of substitution, then the noise source must be within the amplifier itself.

DRIFT, Short Term (up to 5 minutes)

Generally speaking, short term drift on any reference supply should not exceed 10 ppm to 20 ppm of the supply voltage. After a suitable warm up of the supply, a monitoring check of the output should not exceed the above spec on a peak-to-peak basis. If it does, the following checks are suggested as a means of improving the drift characteristics of the supply.

1. Monitor the key elements associated with the basic operational amplifier

   a) From the formula it can be seen that the reference element (or E_{in}) and the feedback resistor (R_O) are directly proportional to the output voltage. Therefore, if they have a tendency to drift due to a poor temperature coefficient, the output voltage will follow.

   b) It can also be seen from the formula for this type of supply that the input resistor (R_{in}) will be inversely proportional to the output. Therefore, a monitoring check on this component should see an opposite drift tendency compared to the output voltage.

Any correlation of the above checks will indicate which component needs replacement.

2. If the above checks prove to be satisfactory while the output of the supply still has a severe drift tendency, then the problem must be within the operational amplifier itself. In tube-type supplies, this could manifest itself in either the tubes themselves having a temperature drift, or an individual component such as a feedback capacitor being temperature sensitive. In transistor supplies, it would usually boil down to an erratic transistor.

DRIFT, Long Term (1 hour, and beyond related to both time and temperature)

If a reference supply is not meeting its long term stability specifications as called out on the data sheet for a given instrument, then more elaborate steps will have to be taken to verify the extent of the deviation, as well as to pinpoint the area of difficulty.

1. The first check should be a strip chart recording to show the extent of stability deviation with known increments of time. The direction of long term drift may be a clue as to which area of the supply is at fault. Refer to basic formula.

2. The next step would be to substitute the main amplifier elements per the methods used to isolate noise. In this instance, however, the instrument should be placed in a controlled, variable environment (such as a temperature controlled oven and/or humidity chamber) while the element being substituted remains in an external, fixed environment. Varying temperature and/or humidity of the instrument while still monitoring the output with a recorder will satisfy the question as to which element of the supply is contributing to long term drift.

FACTOR

CHECKOUT PROCEDURE FOR THE MODEL 895A REFERENCE SUPPLY

I. Operation of both the high voltage and low voltage sections of the instrument are initially confirmed by:

1) Measuring the 1.1V, 11.0V, 110V, and 1100V outputs of the two supplies.

2) Monitoring TP108 with a scope (Ac coupled, Hor. 5 ms/cm, Ver. 0.1V/cm).

Any malfunction in either supply will cause a deviation from the waveform as shown on the Reference Supply schematic.

NOTE: The instrument must be switched to the 100V or the 1000V Range. The common input terminal is Common #2 only when in the TVM mode, Positive Polarity.

II. If TP108 does NOT yield the appropriate waveform, then,

1) Switch the instrument to the 10V Range. (This removes 1500V from all boards and components.)

2) Remove the shield over Q105 and ground its base to Common #2.

If the waveform at TP108 is now CORRECT, the problem is in the Series Pass and Driver Section, the Low Voltage Supply, or the Feedback Divider String.

III. If TP108 still does NOT yield the proper waveform (squared, or saturated), then,

1) Connect the Summing Junction (junction of R122 and R123) to TP404 directly. The supply should now work with about 3% of regulation. This means that the Series Pass and Driver are o.k. The problem must then be in the Chopper Stabilized Amplifier, or the +18V that supplies it.

2) If the supply still does NOT work, there must be problems in both sections. Check the +18V Supply thoroughly first to insure that there will be a good reference.

IV. A check of the voltages associated with the Series Pass Elements in the High Voltage Section should show the following voltage drops:

1) Across Q401, 280V

2) Across Q402, 120V

3) Across Q404, 18V

4) Across each Filter Capacitor, 400V

FLUKE

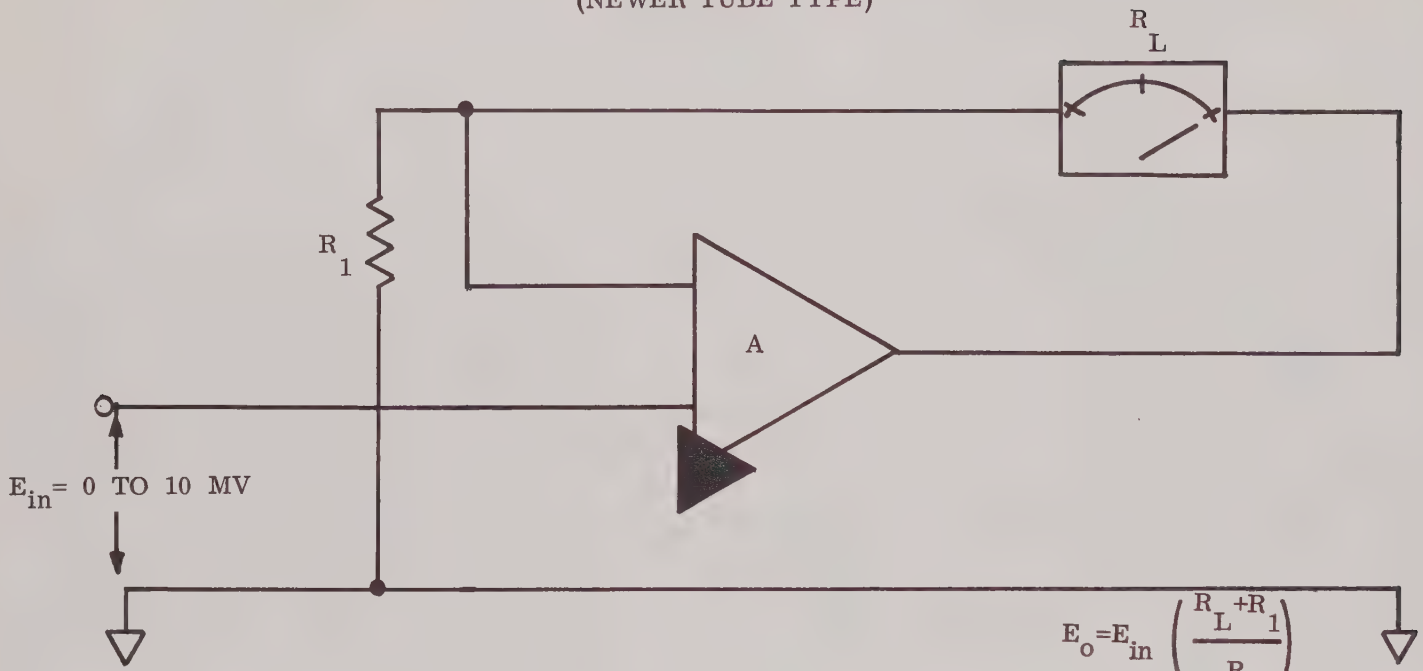
NOTES

FLUKE

NOTES

M1
S5A
S5B
RECORDER OUTPUT
J4
J5
R223 22K
R224 47K
R1 10K
R225 47K
Q207
Q206
CR201
R221 270K
C211 10
V203
R230 47K
R211 10K ZERO ADJ
R220 100
R212 100K
R213 10
C209 5
C210 1250
C205 1250
FROM DS203
R218 27K
Q205
R219 47K
R217 100K
C208 .0047
R216 180K
Q204
C207 .1
R209 100K
Q203
R210 2.2M
Q202
R208 10M
Q201
R215 10K
C206 400
R206 10K
C204 180PF
R207 1M
C203 .047
V202
V201
FROM DS202
FROM DS203
R202 470K
C202 .22
C201 .22
DS201 NE2E
R201 270K
R204 68
R205 5300 CAL
R203 10.7
GUARD
+18V
-18V
+500V
FREQ ADJ
R226 100K
C212 .047
R227 390K
R228 390K
DS202 DS203 NE2H
TO V201 & V203
TO V202
CHOPPER DRIVE

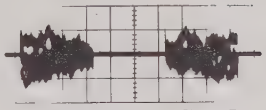
CHOPPER STABILIZED NULL DETECTOR
(NEWER TUBE TYPE)



(SCHEMATIC DESIGNATION) (NOMINAL VALUES)

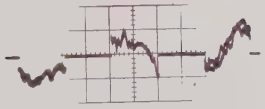
MODEL #	R_1	R_L	R_1 (TT)	R_1 (SS)	I_{R_L}
801B	R218, R219		100Ω	N/A	
803B	R218, R219		100Ω	N/A	
803D	R203, R204, R205	M1	10Ω	10Ω	
825A	R220, R221, R222		10Ω	10Ω	100ua
821A	R203, R204, R205		10Ω	10Ω	
823A	R203, R204, R205		10Ω	10Ω	

.005V/CM



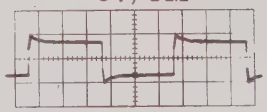
SHORTED C207

.05V/CM

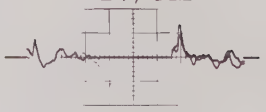


SHORTED C212

CHOPPER DRIVE
5V/CM



2V/CM



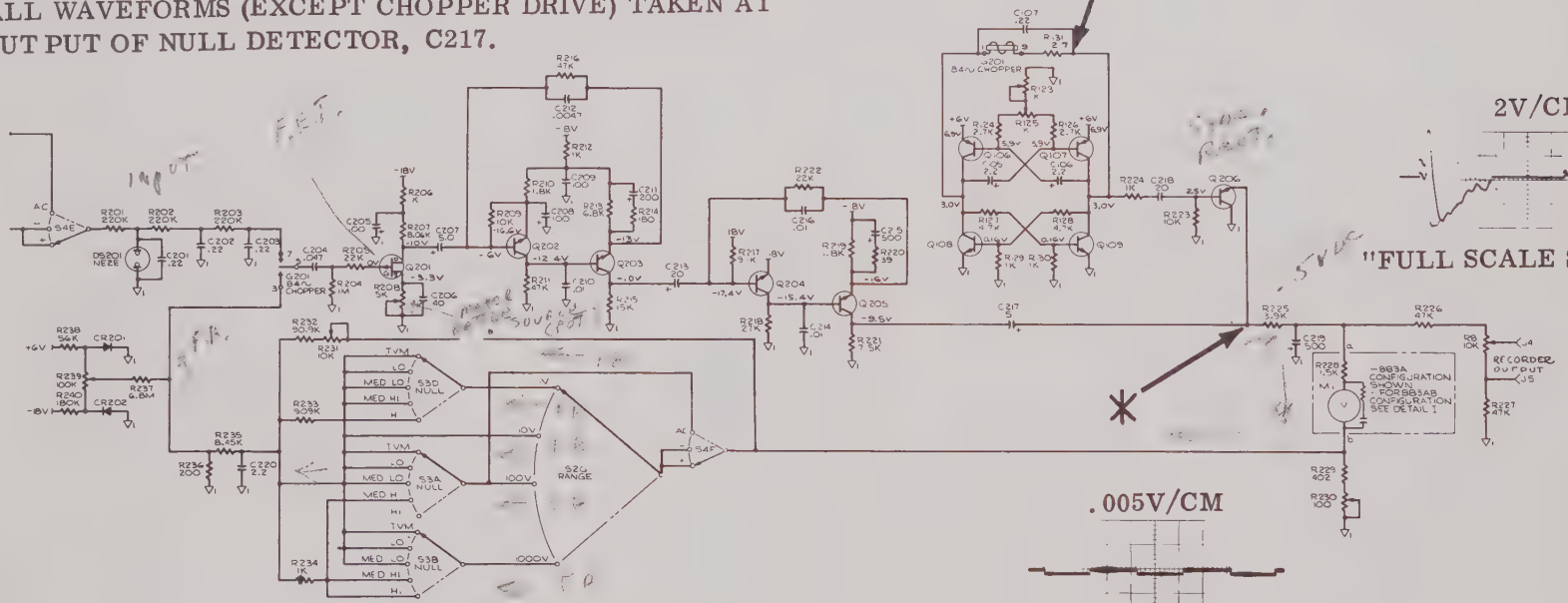
"NO SIGNAL"

CONDITIONS OF MEASUREMENT:

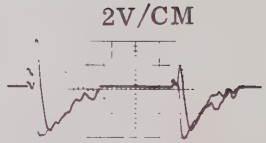
INSTRUMENT: INPUT SHORTED, GROUNDING LINK BETWEEN COMMON A CHASSIS

SCOPE: HORIZONTAL SWEEP, 2MS/CM

* ALL WAVEFORMS (EXCEPT CHOPPER DRIVE) TAKEN AT OUT PUT OF NULL DETECTOR, C217.

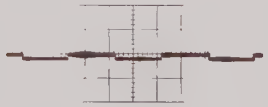


2V/CM



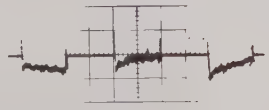
"FULL SCALE SIGNAL"

.005V/CM



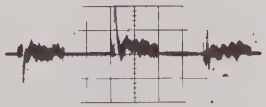
SHORTED Q204, C TO E

.1V/CM



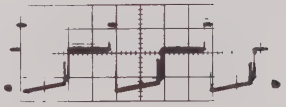
SHORTED Q203, C TO E

.01V/CM



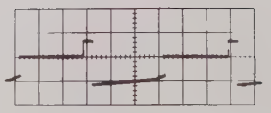
SHORTED C216

2V/CM



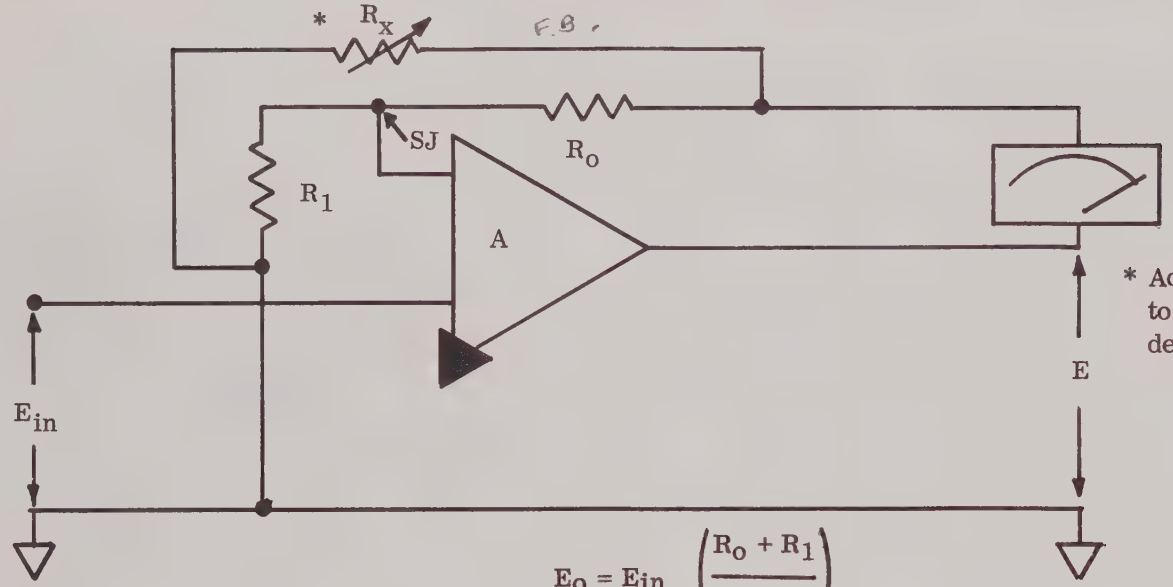
OPEN FEEDBACK TOOP

5V/CM



1V RANGE
1MV NULL
1V DIALED ON K-V

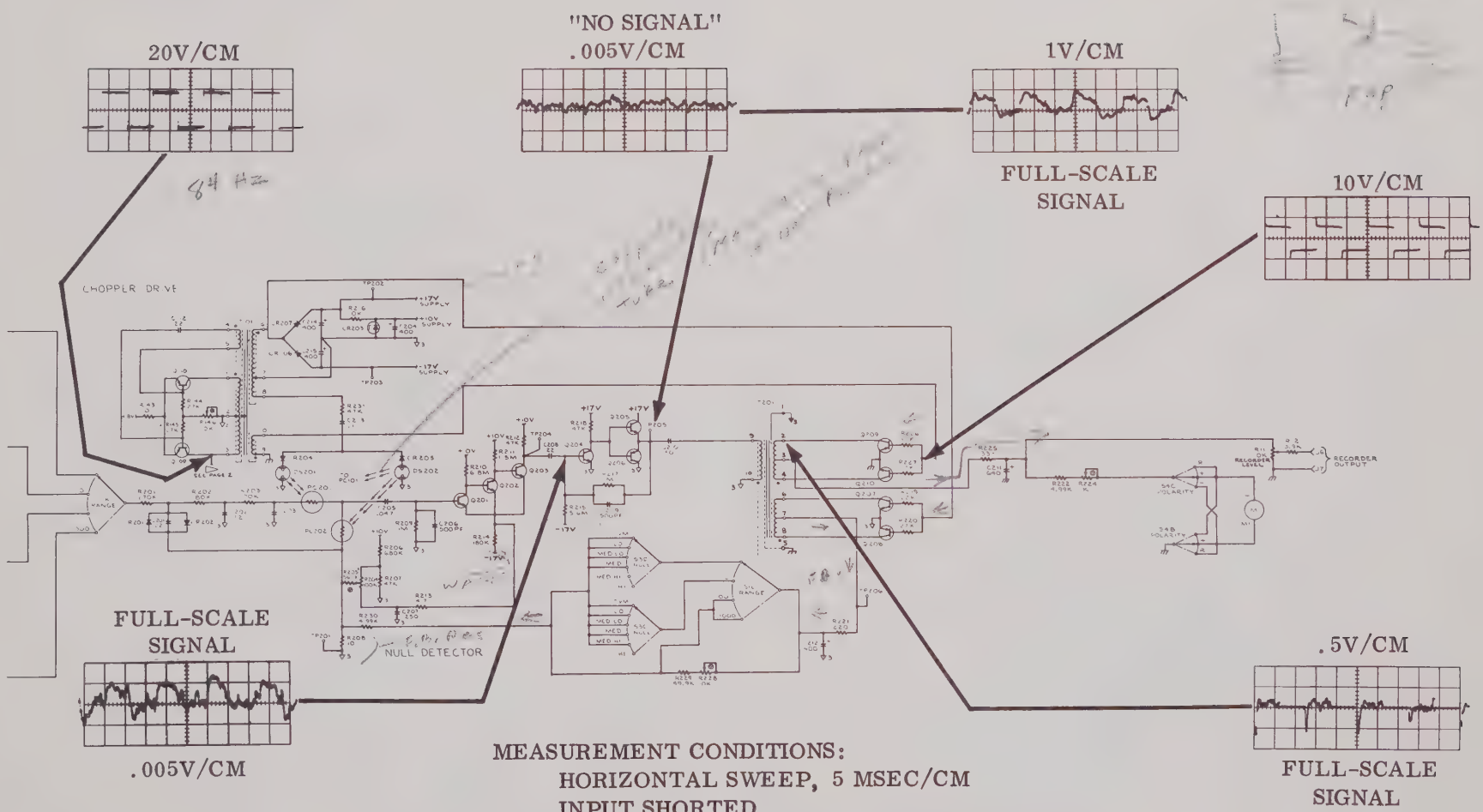
CHOPPER STABILIZED NULL DETECTOR
(SOLID STATE TYPE)



* Adjusts meter current to establish full-scale deflection.

$$E_o = E_{in}\left(\frac{R_o + R_1}{R_1}\right)$$

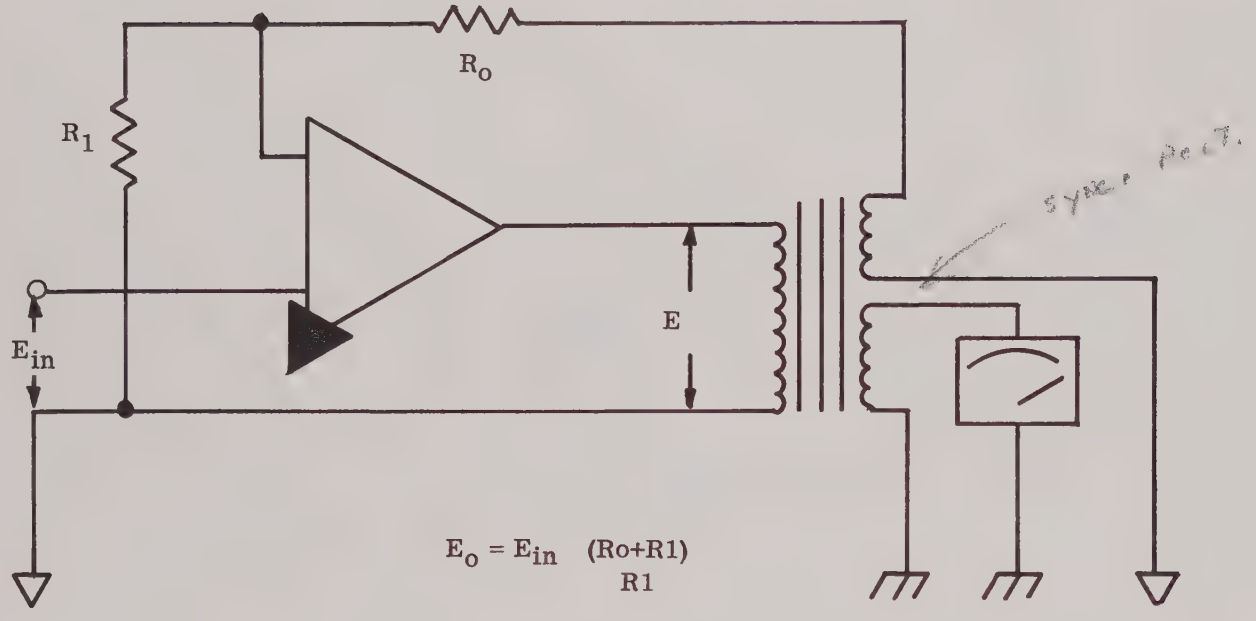
	(SCHEMATIC DESIGNATION)			(NOMINAL VALUES)		
Model #	R_1	R_o	R_x	R_1	R_o	R_x
871A, 873A	R203	R233, R234, R235	R231, R232	200Ω	15.8K	450Ω
881A, 883A	R236	R232, R233, R234, R235	R229, R230	200Ω	8.45K	450Ω



MEASUREMENT CONDITIONS:
HORIZONTAL SWEEP, 5 MSEC/CM
INPUT SHORTED
FULL SCALE DERIVED FROM KELVIN-VARLEY

CHOPPER STABILIZED NULL DETECTOR

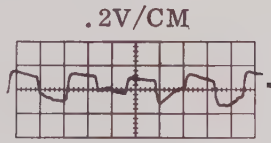
(SOLID-STATE TYPE-885A, 895A)



$$E_o = E_{in} \frac{(Ro+R1)}{R1}$$

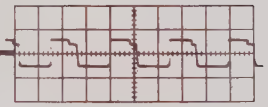
(SCHEMATIC DESIGNATION)			(NOMINAL VALUES)	
Model #	R_1	R_o	R_1	R_o
885A, 895A	R208	R228, R229, R230	10Ω	4.99K

MEASUREMENT CONDITIONS:
HORIZONTAL SWEEP: 5 MSEC/CM
PROBE: X10



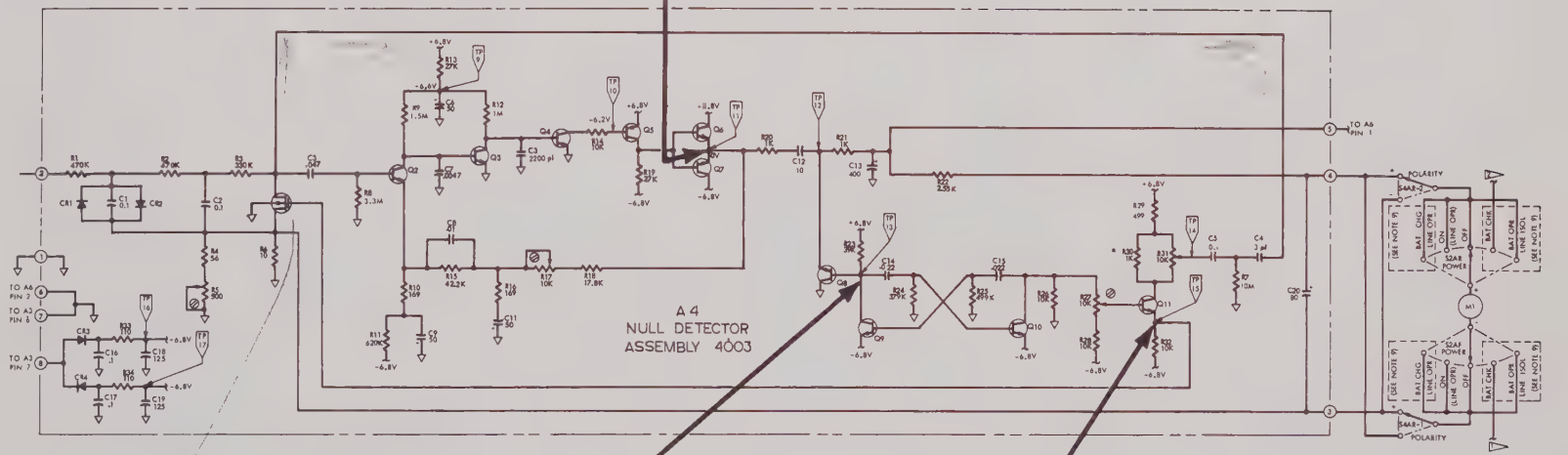
.2V/CM

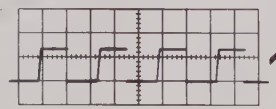
FULL-SCALE SIGNAL



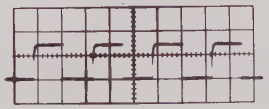
1V/CM

SATURATED



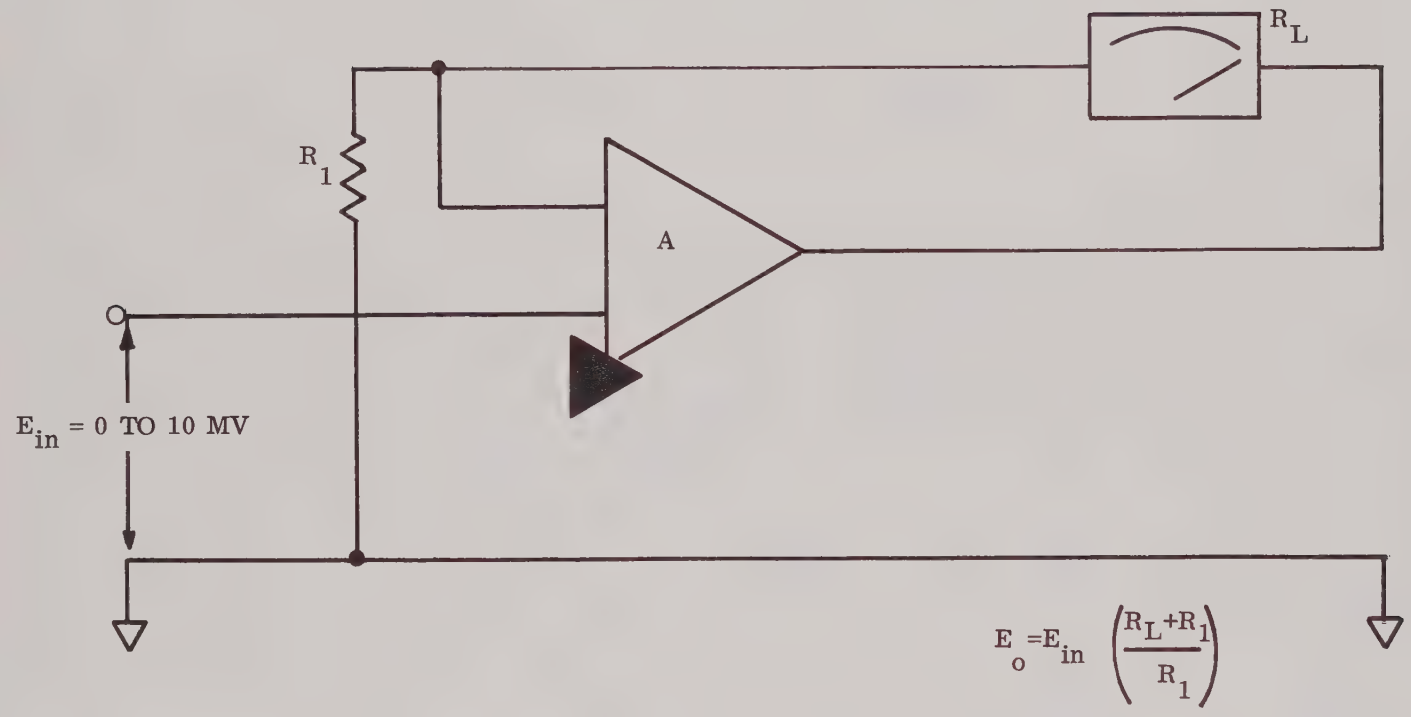


.5V/CM

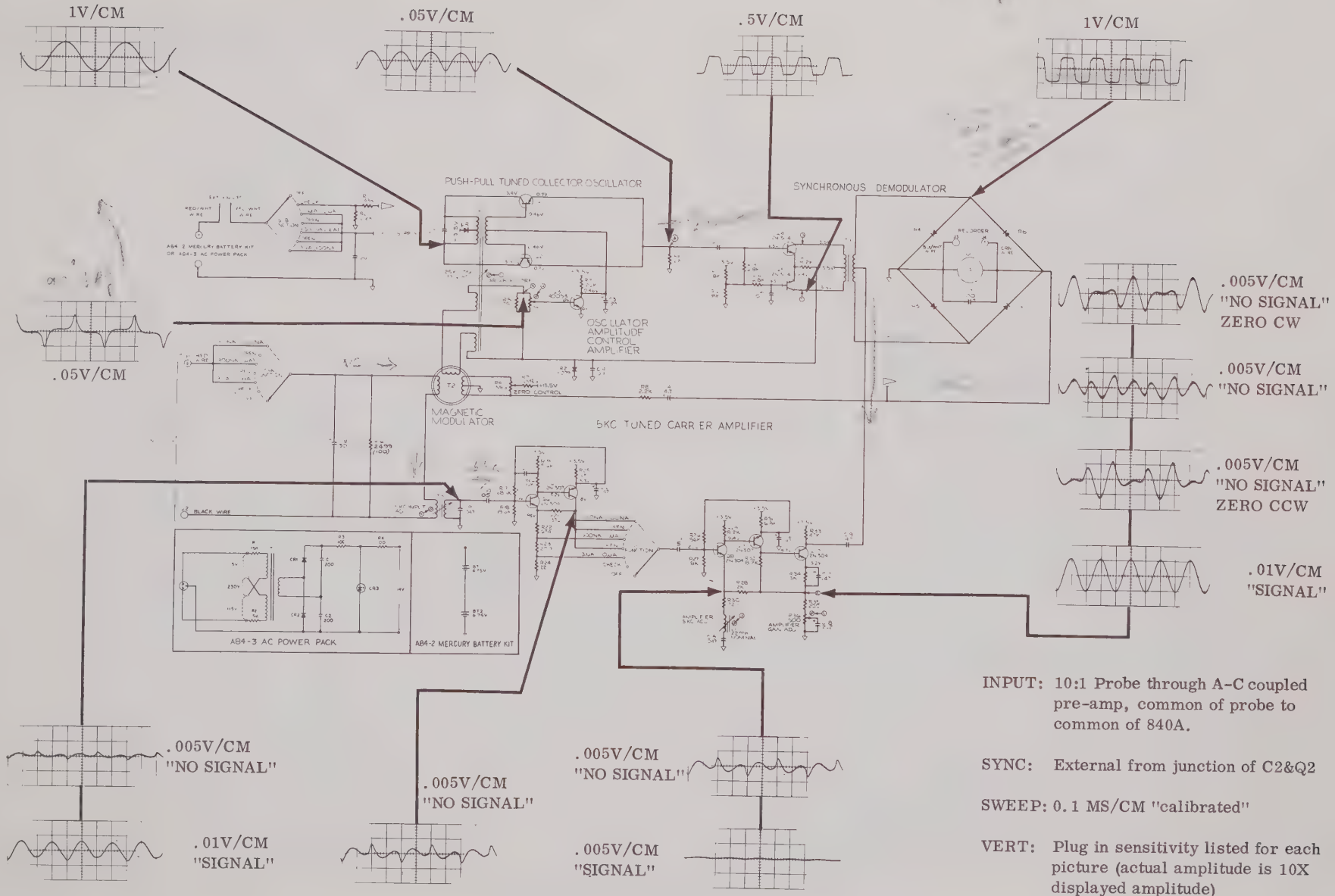


.2V/CM

CHOPPER STABILIZED NULL DETECTOR
(SOLID STATE TYPE)



	(SCHEMATIC DESIGNATION)		(NOMINAL VALUE)	
MODEL #	R_1	R_L	R_1	R_L
891A	R_6	M_1	10Ω	100 ua



INPUT: 10:1 Probe through A-C coupled pre-amp, common of probe to common of 840A.

SYNC: External from junction of C2&Q2

SWEEP: 0.1 MS/CM "calibrated"

VERT: Plug in sensitivity listed for each picture (actual amplitude is 10X displayed amplitude)

1. 2.5KHZ Q2, C2

2. CURRENT IN MODULATOR DRIVE

2.a. IDEALIZED FLUX CORE a

2.b. CORE b

2.c. NET

3. 5KHZ FROM NET FLUX AT TUNED SECONDARY OF T3

4. PRE-AMP OUT (N.S.)

5. Q8 EMITTER

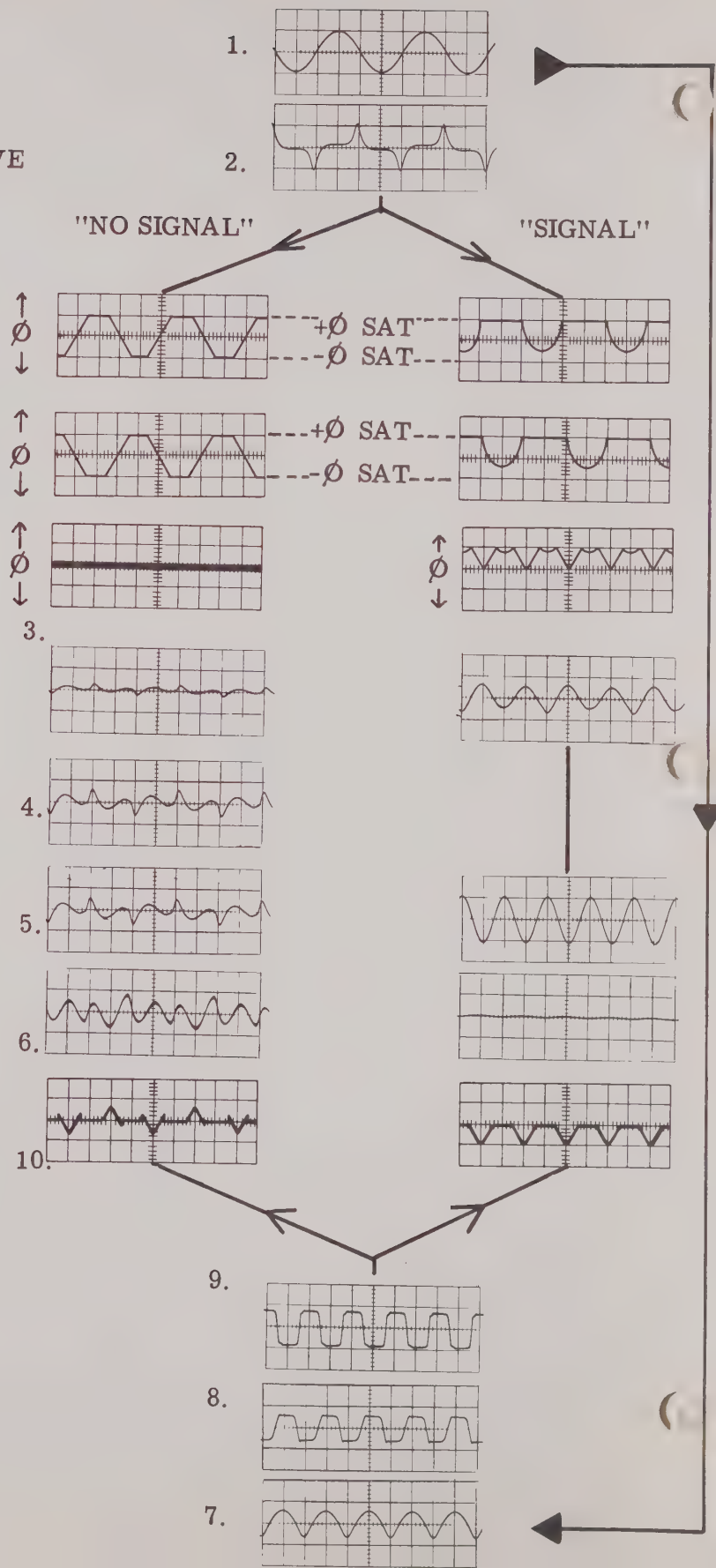
6. TEST POINT (E)

10. RESULTANT METER SIGNAL

9. JUNCTION CR4, &CR6

8. COLLECTOR Q5

7. WAVE FORM AT R10



Does the Battery check o.k. via the front panel controls?

A. Is there continuity of battery EMF from the battery to Flag Note #1 in the "CHECK" mode, and to C1 in all other Power "On" modes?

B. Is the meter movement open?

C. Is capacitor C7 shorted?

Can the meter be zeroed in the "OPEN" position?

A. Does manipulation of the zero control cause normal sensitivity? (Approximately ±1/3 full-scale).

1) Is the sensitivity high, low, or is the meter "dead"?

a) Check the "no signal" waveforms.

2) Is the meter noisy? (Specification: 2 nanoamp p-p for 840A).

a) The "no signal" waveforms should not display amplitude or phase jitter.

Does the meter respond to a full scale input signal on all Ranges?

A. Is the response in tolerance?

1) Do the "signal" waveforms compare to the waveforms at the bottom of the schematic? How about the demodulation waveforms?

2) What is the input impedance?

3) Is the meter calibrated?

4) If the meter is out of tolerance on some Ranges, but not others, what does a check of R21 thru R24 indicate?

B. Is the meter noisy under a "signal" condition where it wasn't under "no signal" conditions?

1) Check the input components.

2) Check the element potentials of Q6 and Q7, and the stability of the divider resistors, R21 thru R24.

C. Does the meter respond sluggishly?

1) What does a check of the feedback response loop comprised of C4 and R8 indicate?

If the response to the above questions is satisfactory, the instrument will respond to calibration.

INTERROGATION OF VOLTMETER NULL DETECTORS

I. With the instrument turned "ON", what is the action of the front panel meter?

A. Does it fluctuate slightly during turn-on? ← should deflect & drop back
B. Does it remain "dead" during, and after, turn-on?
C. After the instrument has been on for a few moments, does the meter pin to left or right full-scale?

II. Is the chopper drive oscillator functioning?

A. This can be observed by listening for the sound of a mechanical chopper, observing the lite source for a photo chopper, or by checking the waveform of either with a scope.

III. Before checking other operational characteristics of the null detector amplifier, observe the meter needle to note whether or not there is a rattle present---and to what extent. ± .5 DIV with short & K-V ⇒ zero

IV. If the meter needle fluctuates as in I. A., above, and restores to zero after the instrument has been on a few moments----check the electrical zero (either at the front panel, or on the PCB). CONSTANT ±1 DIV. IS TOO NOISY

A. Does the electrical zero control have any effect on the meter needle?
1) In the most sensitive null mode of most of the Differential Voltmeters there will be a movement of approximately ±2 to ±6 small divisions on either side of zero.

V. If the meter remains "dead" during, and after, turn-on----what does a check of the meter movement show?

A. Is the suspension broken?
B. Is the meter movement open?

VI. If the meter assumes a "pinned" condition as in I. C., above, obviously the meter movement is not "dead". Other checks of the amplifier will have to be made to determine the nature of the difficulty.

VII. What occurs when a signal that is compatible with the position of the Range and Null switches is inserted at the front panel?

A. Does the meter deflect correctly?
B. Is there any response at all?
C. Does the meter "pin" with any applied signal on either TVM or Null?
D. Is it certain that an input signal at the front panel is reaching the Null Detector? Check continuity to amplifier input.
E. What happens if a signal whose magnitude represents the basic sensitivety of the amplifier is injected between the input filter and common (bypassing all switch networks).

In short, and in general, an interrogation of a Null Detector should derive answers to, at least, these pertinent questions?

1) Is the malfunction solely within the null detector amplifier?
2) Is the symptom that of noise, saturation, erroneous gain, or non-operation?

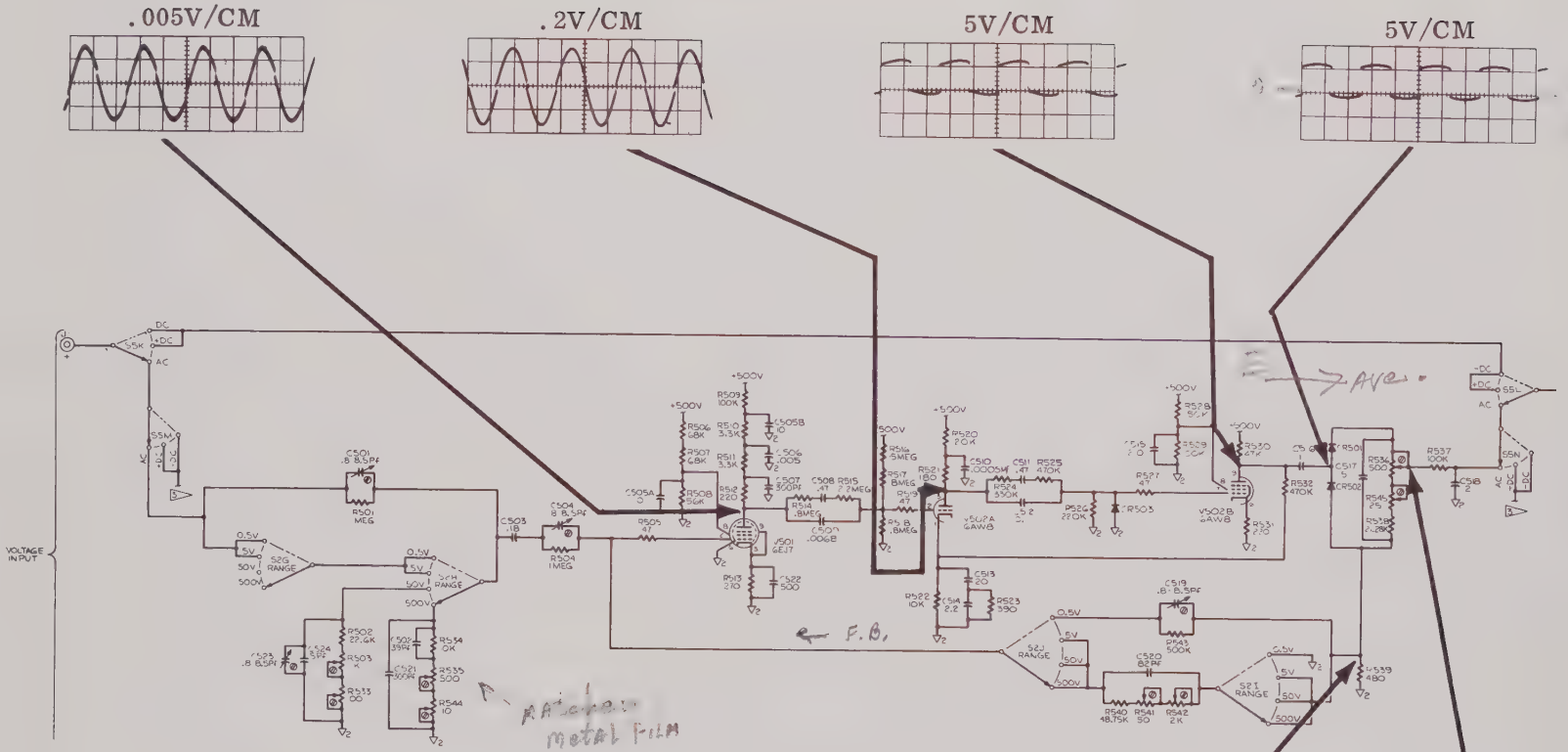
A. Noise will usually predominate in the low level stages at the input of the amplifier.
B. Saturation will occur with an open feedback loop.
C. Erroneous gain can be attributed to individual stages, or out-of-tolerance R_i or R_o.
D. Non-operation can reflect an open meter circuit, missing supply voltages, or no input signal path.

FLUKE

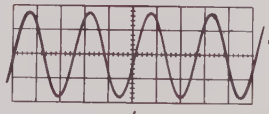
NOTES

FLUKE

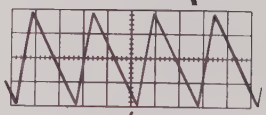
NOTES



HORIZONTAL SWEEP: 1MSEC/CM
INPUT SIGNAL: 5VAC, 400Hz



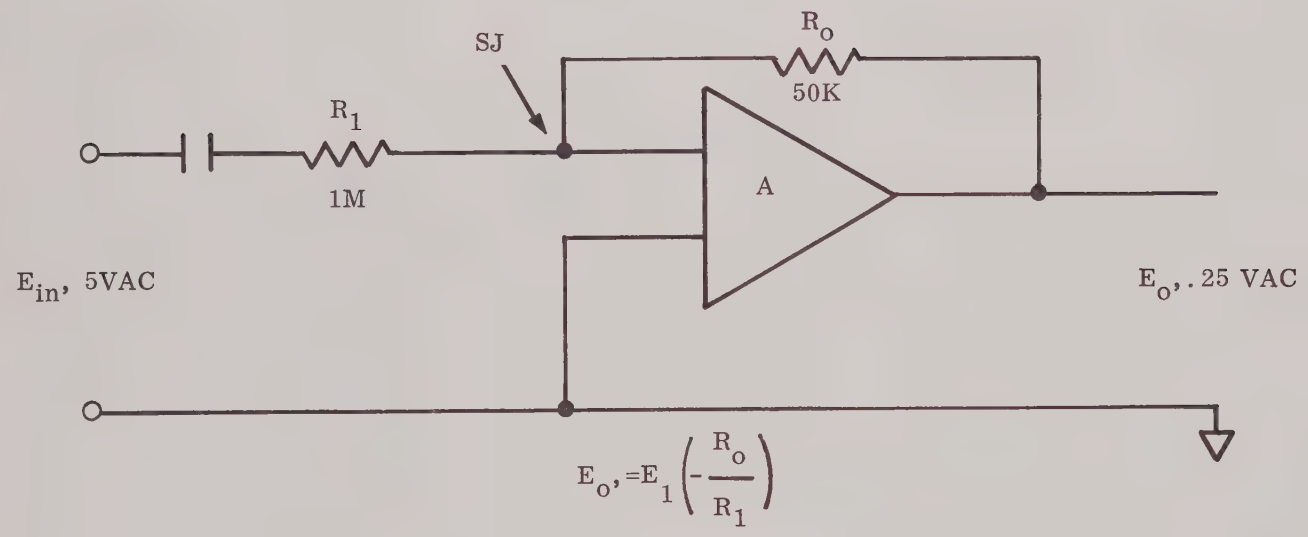
.2V/CM



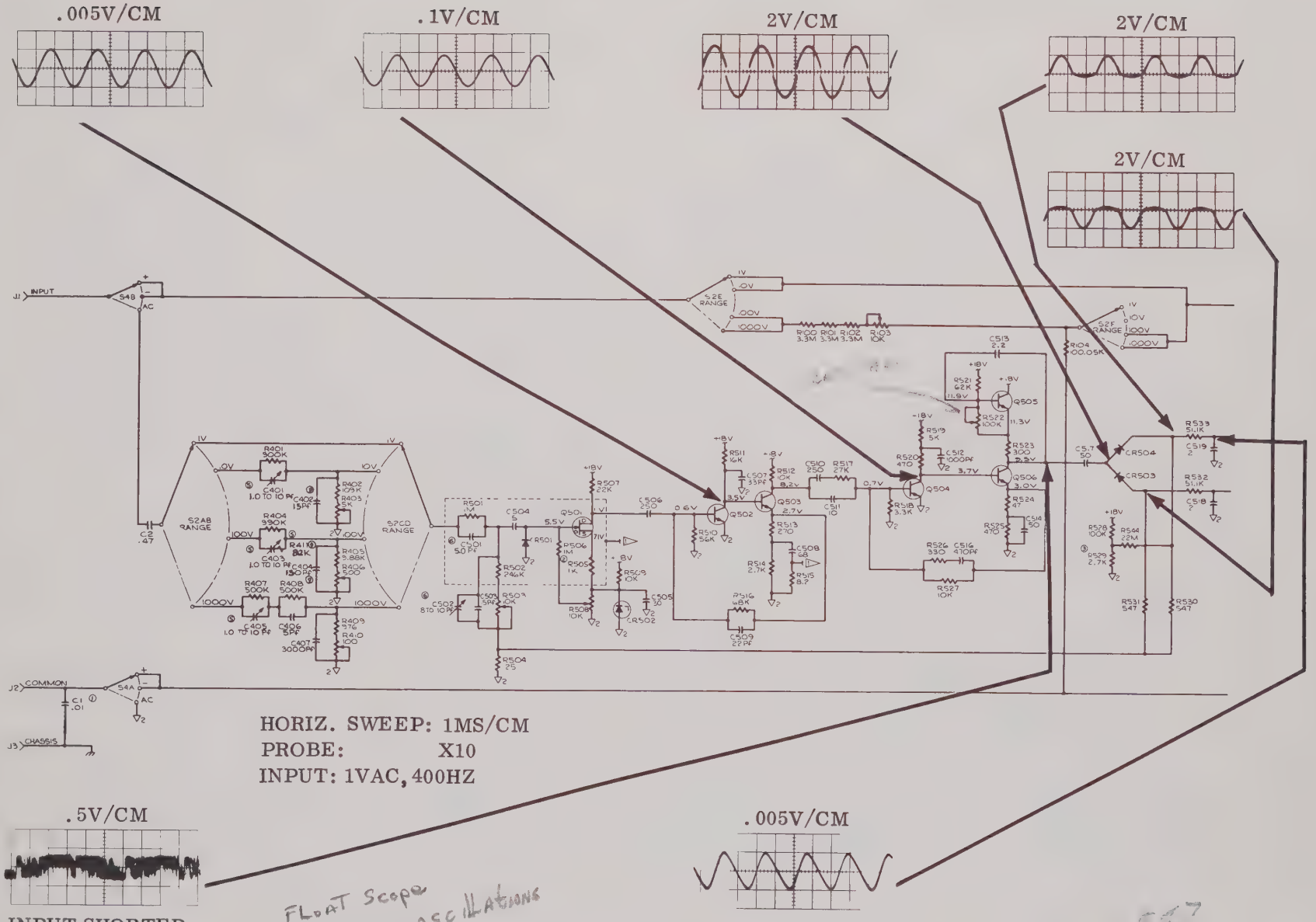
.2V/CM
(R539 SHORTED)

NOT spec'd Below 1MV.
Because of Noise 40-140MV
(Low Volts - Hi Freq Error)

CONVERTER AMPLIFIER
(TUBE-TYPE)



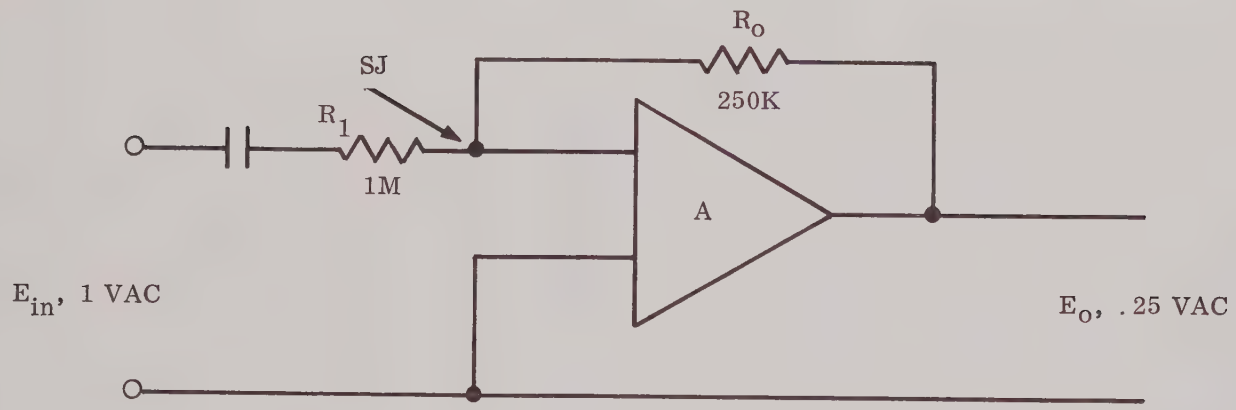
MODEL #'S	(SCHEMATIC DESINATIONS) R_1	R_o	(NOMINAL VALUES) E_{in}	R_1	R_o
803B	R504	R541, R542			
803C					
803D	R504	R540, R541, R542	5VAC	1M	50K
823A					



FLOAT Scope
To Avoid oscillations

883 - 887
Solenoid Converter

CONVERTER AMPLIFIER
(SOLID-STATE TYPE)



$$E_o = E_{in}\left(-\frac{R_o}{R_1}\right)$$

MODEL #'S	(SCHEMATIC DESIGNATIONS)		(NOMINAL VALUES)		
	R_1	R_o	E_{in}	R_1	R_o
873A 883A 887A	R501	R502, R503	1VAC	1M	250K

INTERROGATION OF CONVERTER AMPLIFIER
(SOLID STATE)

The approach in determining whether or not a AC to DC converter is a properly operating block element in a device such as a differential voltmeter should be guided by the following criteria:

A. Are the supply voltages correct in terms of magnitude and ripple?
B. Does the amplifier have a low residual noise?
C. Is the amplifier free of oscillation susceptibility?
D. Does the amplifier have sufficient and proper gain?

I. When the instrument is first turned on in the AC mode, does the meter needle undergo several gyrations before it settles down to a zero position?

A. This is perfectly normal, and is a function of the varying time constants throughout the amplifier.

II. What is the condition of the B+ voltages applied to the converter?

A. If the supply voltage is the 500V Reference Supply, its condition should be well known from the DC operating conditions of the instrument.
B. If the B+ supply is an independent supply such as in the solid state units, then it should be checked for proper operation prior to checking out the converter amplifier.

III. With a shorting bar placed into the input terminals, the Range switch turned to the lowest voltage range, and the Null switch turned to the most sensitive range, what is the magnitude of residual amplifier noise as seen on the front panel meter?

A. Is it less than the specification of "up to 140 uv"?
B. If more than 140 uv, does it appear that the amplifier is in oscillation? — See II A

IV. Is the noise "passive" or "active"? And how much of each type is present?

A. Active and passive noise is defined as a function of source. If it is due to transistors, it is active. If it sourced to diodes, resistors, capacitors, or external supply voltages, it is considered passive.
B. A further definition that may be helpful is that active noise is usually diminished under signal conditions due to the feedback of the amplifier and its associated "quieting" effect. However, passive noise is present in a constant magnitude regardless of signal conditions.
C. A quick check to isolate noise is accomplished on solid state instruments by shorting the feedback loop to common at the summing junction and observing the meter deflection. As long as the deflection is 80 millivolts, or less, the situation is normal, because what is being observed is the amplified noise that is attributed to the FET as an active component. (Since the gain of the amplifier under these open loop conditions is approximately 1000, then the amount of noise attributed to the FET is approximately 80 microvolts.)

V. While the amplifier is in the open loop state as in IV. C., above, this is a good time to check all of the element potentials since the amplifier is less likely to break into oscillation as a function of metering instruments connected to its various stages.

VI. Is the amplifier susceptible to oscillation?

A. The meter itself may indicate a condition of oscillation if it is noted that the residual noise (as seen via the shorting bar test) is double or triple the 140 uv maximum. Also, if the meter is pinned in any voltage or null range without an input signal, the amplifier is either oscillating, or else it has a catastrophic failure in some stage(s).
B. The shorting out of the feedback loop as in IV. C. is also a good method of finding out whether or not the cause of oscillation (if it exists) is associated with the feedback loop. If oscillation persists with the feedback loop shorted, then a problem exists in the amplifier proper.

In summary, the interrogation of the converters will supply answers that will generally fall in these categories:

A. Active noise will usually be sourced to the FET.
B. Passive noise will usually be associated with components at the input stage, or possibly from the B+ supply if it has a high ripple component.
C. Oscillation of a high magnitude will generally be attributed to the capacitance characteristics of the FET, or other components at the input stage.
D. Oscillation at lower levels may be found in either of the doublet stages, but probably the first one.
E. High frequencyoscillation will also be associated with the FET.
F. Low frequency oscillation will most likely be associated with the coupling capacitors between stages----and particularly the higher value caps.
G. Frequency and gain problems are most likely to be found in the input attenuator.

KELVIN-VARLEY CALIBRATION

If it has been determined that the Kelvin-Varley divider is in need of complete calibration, the following procedure can be used. This need will have been determined by either having performed a linearity check, or by the necessary replacement of one, or more, resistors.

The equipment needed for this calibration is as follows:

Stable power source of approximately 3V to 5V. This is most easily supplied by batteries.

Standard Kelvin-Varley Divider, Fluke Model 720A.

High impedance null detector, Fluke Model 845A.

Single-pole, single-throw switch for switching applied voltage.

Assorted test leads.

Calibration is performed by disassociating the K-V from the rest of the instrument. This means simply disconnecting the input lead from the K-V PCB. (It is optional as to whether the common lead is removed since it is tied to the common input binding post in the TVM mode, and this can be used as a connection point). Then proceed as follows:

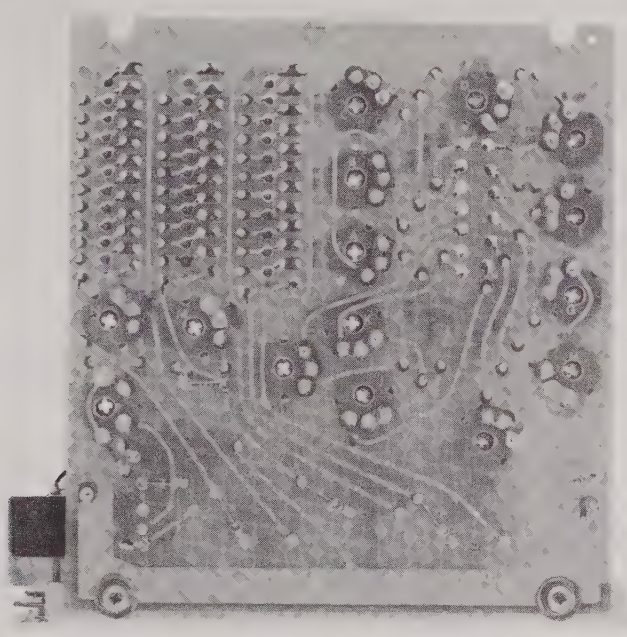
1. Unsolder one end of the buss wires (U, V, W, X, Y, Z) so as to isolate each decade, and also to use these wires as connecting points.
2. Set the "E" decade to some point away from its end. All other dials to zero.
3. Connect the Standard K-V divider in place of buss wire Z.
4. Connect the null detector between point 15 and the output binding post of the Standard K-V.
5. Via the toggle switch (in open position), connect the voltage source --- approximately 5V.
6. Dial the Standard K-V to .5000000, close the toggle switch, and adjust P for a null on succeedingly more sensitive null ranges of the null detector.
7. Remove Standard K-V, null detector, and power source. Resolder buss wires Z and Y.

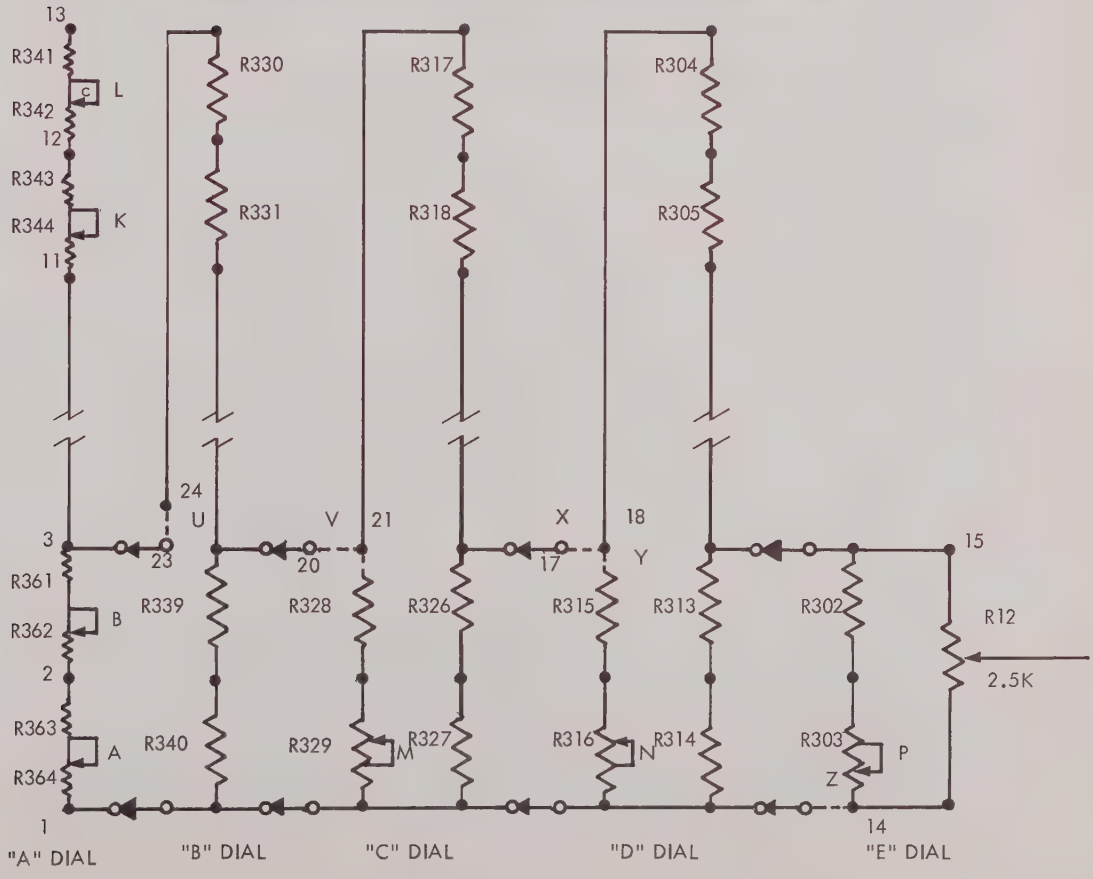
Repeat the same set-up for the succeeding decks by inserting the bridge configuration in place of buss wire X for the null adjustment of N, and in place of buss wire V for the null adjustment of M. Note that after the adjustment of N, buss wires W and X are resoldered. And after the adjustment of M, buss wire V is resoldered.

When placing the bridge configuration in place of buss wire U, a slightly different procedure will be followed.

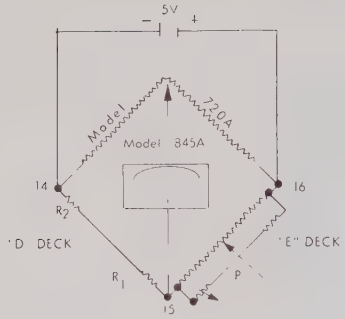
1. Redial the Standard Kelvin-Varley Divider to either .6666666 or .3333333, depending upon which way the K-V is inserted into the bridge. The reason for this is apparent in the next step.
2. Short out points 2 and 3 and adjust A for null.
3. Remove this short, and now short out points 1 and 2 for the adjustment of B for null.
4. Advance the "A" Dial two positions and repeat the process by shorting out one or the other sets of points.
5. Continue this process to the top end of the "A" Decade.
6. Remove the Standard K-V, the Null Detector, and the power source. Resolder buss wire U.

This completes the calibration of the Kelvin-Varley Divider.




13
R341
L
R342
12
R343
R344
K
11
R330
R331
R317
R318
R304
R305
24
U
V
21
X
18
Y
3
23
20
17
15
R361
R362
B
2
R363
R364
A
1
R339
R340
R328
R329
R326
R327
M
R315
R316
N
R313
R314
R302
R303
P
Z
R12
2.5K
14
"A" DIAL
"B" DIAL
"C" DIAL
"D" DIAL
"E" DIAL

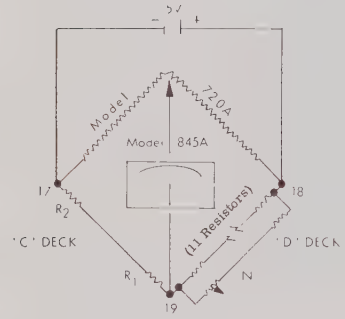
"E" DECK CALIBRATION



SETUP CONDITIONS

1. The entire "E" Deck, and any two resistors of the "D" Deck are connected to 720A in Ratio Bridge.
2. Model 720A dialed to.5000000.
3. Model 845A set to 30uv Range.
4. Adjust P for null ± 25uv.
5. Rotate "D" Decade to check the linearity of the "D" Deck resistors.(typically within 20uv)

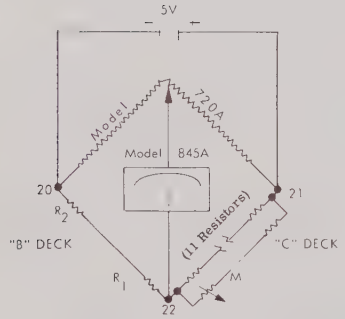
"D" DECK CALIBRATION



SETUP CONDITIONS

1. The entire "D" Deck ,and any two resistors of the "C" Deck are connected to the 720A in a Ratio Bridge.
2. Model 720A dialed to .5000000.
3. Model 845A set to 100uv Range.
4. Adjust N for null ±25uv.
5. Rotate "C" Decade to check the linearity of the "C" Deck resistors. (typically within ±15uv)

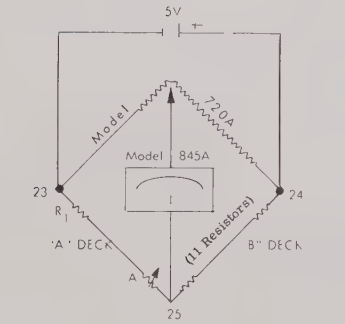
"C" DECK CALIBRATION



SETUP CONDITIONS

1. The entire "C" Deck and any two resistors of the"B" Deck are connected to the 720A in a Ratio Bridge.
2. Model 720A dialed to .5000000.
3. Model 845A set to .30uv Range.
4. Adjust M for null ±10uv.
5. Rotate "B" Decade to check the linearity of the "B" Deck resistors.(typically within ±6uv)

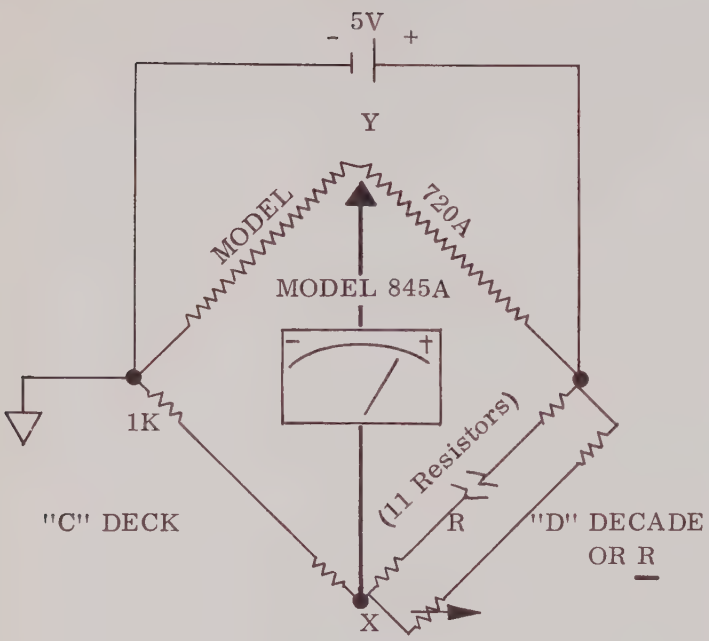
"A" DECK CALIBRATION



SETUP CONDITIONS

1. One resistor and associated pot and the entire "B" Deck is connected to the 720A in a Ratio Bridge.
2. Model 720A dialed to.3333333.
3. Model 845A set to 10uv Range.
4. Adjust A for null ±1uv.

EXAMPLE OF CALIBRATION ATTAINBILITY



GIVEN:
1) The 845A is off-null by 10uv.
2) The setup is comparing the "D" Deck to any two resistors of the "C" Deck.
3) Battery Voltage, 5V.
4) Model 720A dialed to .5000000.

QUESTION:

Under these conditions, how far away is the adjustment for a null in ppm of resistance?

SOLUTION:

Voltage at point Y = 2.5V

Voltage at point $X = \frac{5(2\times10^3)}{R+(2\times10^3)}$

$$X-Y = 10^{-5}V$$

$$\frac{5(2\times10^3)}{R+(2\times10^3)} - 2.5 = 10^{-5}$$

SO,

$$10^4 - 2.5R - (5\times10^3) = 10^{-5}R + 10^{-5}(2\times10^3)$$

$$5\times10^3 - 10^{-5}(2\times10^3) = 2.5R + 10^{-5}R$$

$$\frac{5000-.02}{2.50001} = R$$

$$\frac{4999.98}{2.50001} = R$$

ANS: 1999.988=R, or 12 parts in 2 million, or 6 ppm.

NOTE: Matching for this deck need only be as good as 400 ppm.

MODEL	VOLTAGE RANGE	NULL SENSITIVITY	NULL DETECTOR INPUT RESISTANCE
801B 803B	All	10 1 0.1 0.01	10 Megohms 10 Megohms 10 Megohms 1 Megohm
825A 821A 803D 823A	All	10 1 0.1 0.01 0.001	10 Megohms 10 Megohms 10 Megohms 10 Megohms 1 Megohm
871A 873A	1000 100	Voltmeter has constant 10 Megohms input resistance	
	10	1 0.1 0.01 0.001	10 Megohms 10 Megohms 1 Megohm 1 Megohm
	1	0.1 0.01 0.001	10 Megohms 10 Megohms 1 Megohm
881A 883A 887A	1000 100	Voltmeter has constant 10 Megohms input resistance	
	10	1 0.1 0.01 0.001	10 Megohms 10 Megohms 1 Megohm 1 Megohm
	1	0.1 0.01 0.001 0.0001	10 Megohms 10 Megohms 1 Megohm 1 Megohm
885A	1000 100	Voltmeter has constant 10 Megohms input resistance	
	10	1 0.1 0.01 0.001 0.0001	10 Megohms 10 Megohms 10 Megohms 1 Megohm 1 Megohm
	1	0.1 0.01 0.001 0.0001	10 Megohms 10 Megohms 10 Megohms 1 Megohm
895A 891A	1000	100 10 1 0.1 * 0.01	100 Megohms 100 Megohms 100 Megohms 100 Megohms * 10 Megohms
	100	10 1 0.1 0.01 * 0.001	100 Megohms 100 Megohms 100 Megohms 10 Megohms * 1 Megohm
	10	1 0.1 0.01 0.001 * 0.0001	100 Megohms 100 Megohms 10 Megohms 1 Megohm 10 Meg * 1 Megohm (891A)
	1	0.1 0.01 0.001 * 0.0001	100 Megohms 10 Megohms 100 Meg 1 Megohm 10 Meg * 1 Megohm (891A)

* 895A ONLY

TRANSISTOR SUBSTITUTION CHART

FOR

FLUKE INSTRUMENTS

MFR. #: A house number as given in the FLUKE Instruction Manual.

JEDEC #: Nearest equivalent to house number for all parameters required.

FLUKE #: The part number assigned to the house number---not necessarily the JEDEC #. Note that each six digit part number shown should be preceded by its Class Code, 4805-. (e.g. 4805-220087)

SOURCE: This indicates the present dominant source used by FLUKE. Other sources may be found besides those shown.

NOTE: A caution is in order when replacing a house number transistor with any one of the JEDEC numbers shown. There may be an individual selection process necessary in order to find the 2N # that will best match the circuitry. It can generally be stated that transistor Beta is the most significant parameter.

MFR. #	JEDEC #	FLUKE #	SOURCE	COMMENTS
A-601	2N2642	220087	Motorola, T I	
CDQ10449	2N3945	153551	Transitron	
CDQ10656	2N3945	193870	Transitron	
CDQ10656	2N3945	217752	Transitron	Selected for low I_{cbo}
CDQ19122	2N2640	168583	Motorola	
CDQ19124	2N2917	171058	Fairchild	
CDQ19125	2N2917	171041	Fairchild	
CDQ19136	2N2223 2N2917	182246	Fairchild Fairchild	
CDQ23102	2N2369	159855	Motorola	
CDQ23153	2N2484	168716	Amperex, Mot.	
CDQ29011	2N2916	180307	G. E., Mot. T. I.	
CDT1444	2N301W 2N285	116707	R. C. A. Delco	

TRANSISTOR SUBSTITUTION CHART FOR FLUKE INSTRUMENTS

MFR. #	JEDEC #	FLUKE #	SOURCE	COMMENTS
CH23030	2N2369	159855	Mot.	
CS23030	2N2369	159855	Mot.	
CS-3638	2N3638	169375	Fairchild	
DF-60526T	2N4339	192864	Siliconix	
F-1047	2N3069	166223	Amelco, U. C., Sil.	
F1417	2N3069	216606	Amelco. U. C., Sil.	
F-5022	2N2608	159210	Amelco, U. C., Sil.	
FN323	2N4339	192864	Siliconix	
FT704	2N4065 2N4352	226043	Fairchild Mot.	
GA2817	2N398A	182600	T. I., R. C. A.	
GA2875	2N1306	182691	T. I., R. C. A.	
GA2877	2N1307	182709	T. I., R. C. A., G. E.	
GME4003	2N2484	168716	T. I., G. E.	
GME9001	2N2369	159855	Mot.	
MPS-3638	2N3638	169375	Fairchild	
MPS3638	2N3638	241141	Fairchild	
MPS3640	2N4352	226290	Mot.	
NS1485	2N4037 2N2095A	218537	R. C. A. Nat. Semicon.	
NS734	2N2222	117192	R. C. A., Mot.	
P1049	2N2608	222158	Amelco, U. C. Sil.	
PF169	no equiv.	229799	Fluke	
S15272	2N3945	153551	Transitron	

TRANSISTOR SUBSTITUTION CHART FOR FLUKE INSTRUMENTS

MFR. #	JEDEC #	FLUKE #	SOURCE	COMMENTS
S19254	2N2484	168716	T.I., G.E.	
S-22650	2N4250	225599	Fairchild	
S-6816	2N2369	159855	Mot.	
S7563	2N2484	168716	T.I., G.E.	
SC4017G	MC1533G	229138	Mot.	
SD4501	2N2918	226019	T.I., Mot., G.E.	
SE6021	2N4410 2N3877A	218503	Mot., G.E. G.E.	
SL213	2N4285	228874	Nat. Semicon.	
SL214	2N4285	241240	Nat. Semicon.	
SL-339	2N4286	225607	Nat. Semicon.	
SL340	2N4286	222869	Nat. Semicon.	
SM4144	2N2904	190389	T.I.	
SM4144	2N2904	159491	T.I.	Selected for Hi C-E breakdown
SM6419	2N2904	190389	T.I.	
SP10406	2N2916	180307	G.E., Mot., T.I.	
SP10422	2N2223 2N2917	182246	R.C.A., Mot. G.E., Mot., T.I.	
SPT93108	2N2484	168716	T.I., G.E.	
SS2104	2N3945	193870	Transitron	
ST1750T631	2N2484	168716	T.I., G.E.	
ST4203	2N2040	117200	Transitron	
ST71010	2N2484	200535	T.I., G.E.	
SU-443	2N2608	159210	Amelco, U.C., Sil.	

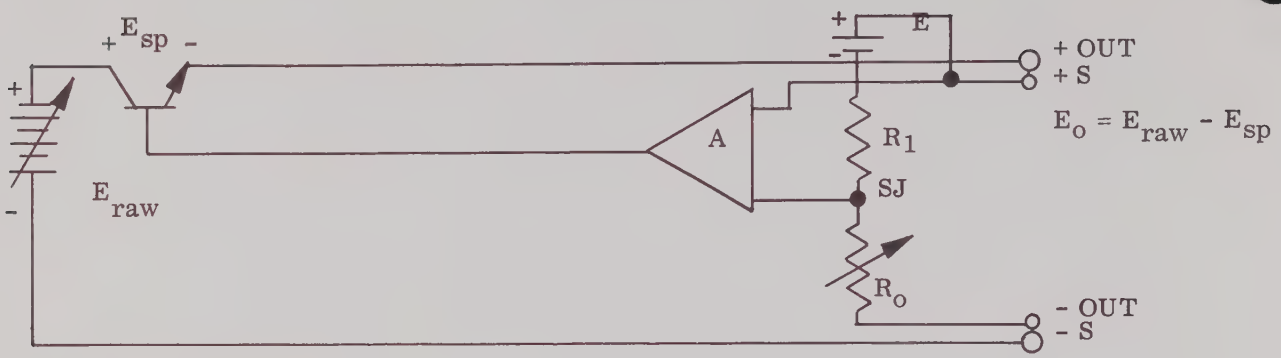
TRANSISTOR SUBSTITUTION CHART FOR FLUKE INSTRUMENTS

MFR. #	JEDEC #	FLUKE #	SOURCE	COMMENTS
TI-496	2N3053	117218	R.C.A.	
U1249	2N3069	166223	Amelco, U.C., Sil.	
U1386	2N4339	192864	Siliconix	
U1766	2N3069	216606	Amelco, U.C., Sil.	
X16E2300	2N4286	222869	Nat. Semicon.	
X22A556	2N2905A 2N4037	218537	Nat. Semicon. R.C.A.	
1095-542	2N3945	193870	Transitron	
11C2322	2N3945	203489	Transitron	
1642031	164-20	193953	Westinghouse	
12E-1516	2N2642	220087	G.E., Mot., T.I.	
320C034H31	164-20	193953	Westinghouse	
35487	2N301W 2N285	116707	R.C.A. Delco	
37959	2N3053	150359	R.C.A.	
38654	2N2905A 2N4037	218537	Nat. Semicon. R.C.A.	
3907	2N404	163188	R.C.A.	
40053	2N3053	150359	R.C.A.	
40231	2N3241	165779	R.C.A.	

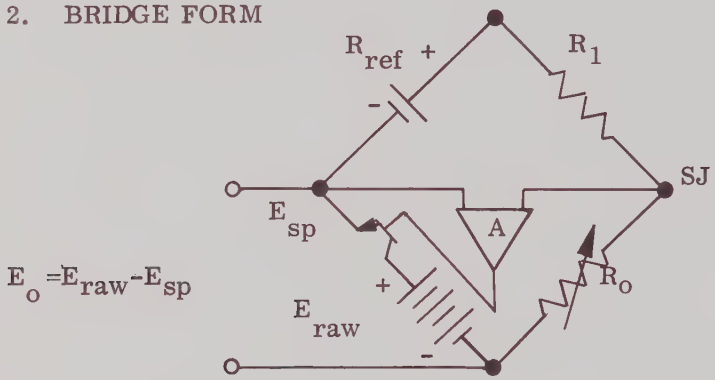
FLUKE

NOTES

1. STANDARD FORM BLOCK DIAGRAM

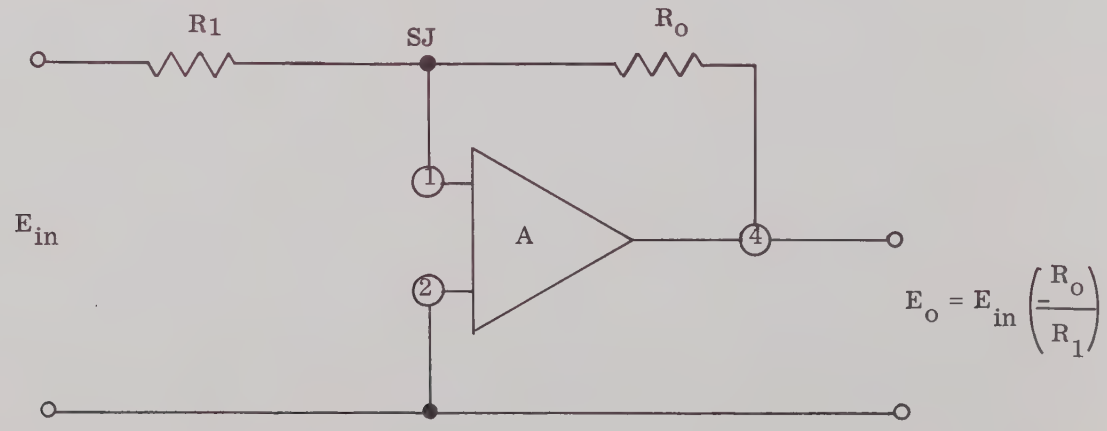


2. BRIDGE FORM



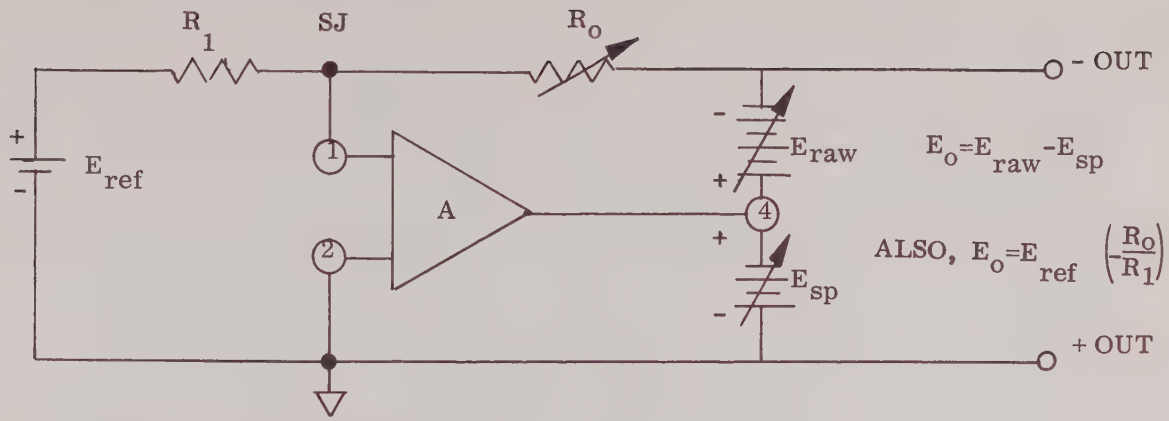
3. OP-AMP FORM

a) STANDARD OP-AMP, INVERTING TYPE

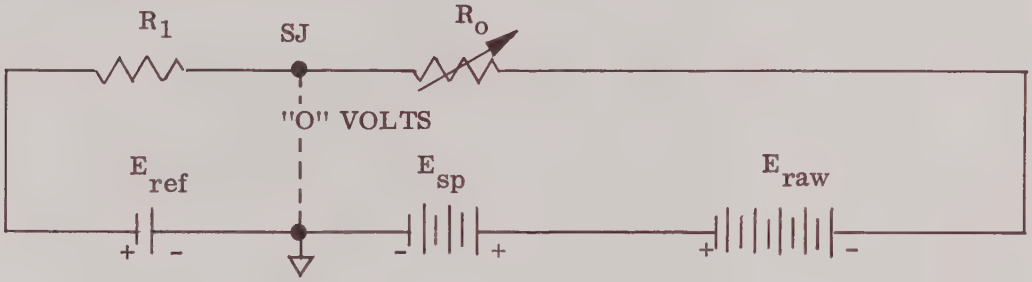


3. OP-AMP FORM, cont.

b) FLUKE ADAPTATION



4. SIMPLIFIED ANALYSIS



$$I = \frac{E_{ref} - E_{sp} + E_{raw}}{R_1 + R_o}$$

IF $E_{r1} = E_{ref}$, THEN E_{SJ} (SUMMING JUNCTION) TO $\perp$ = O

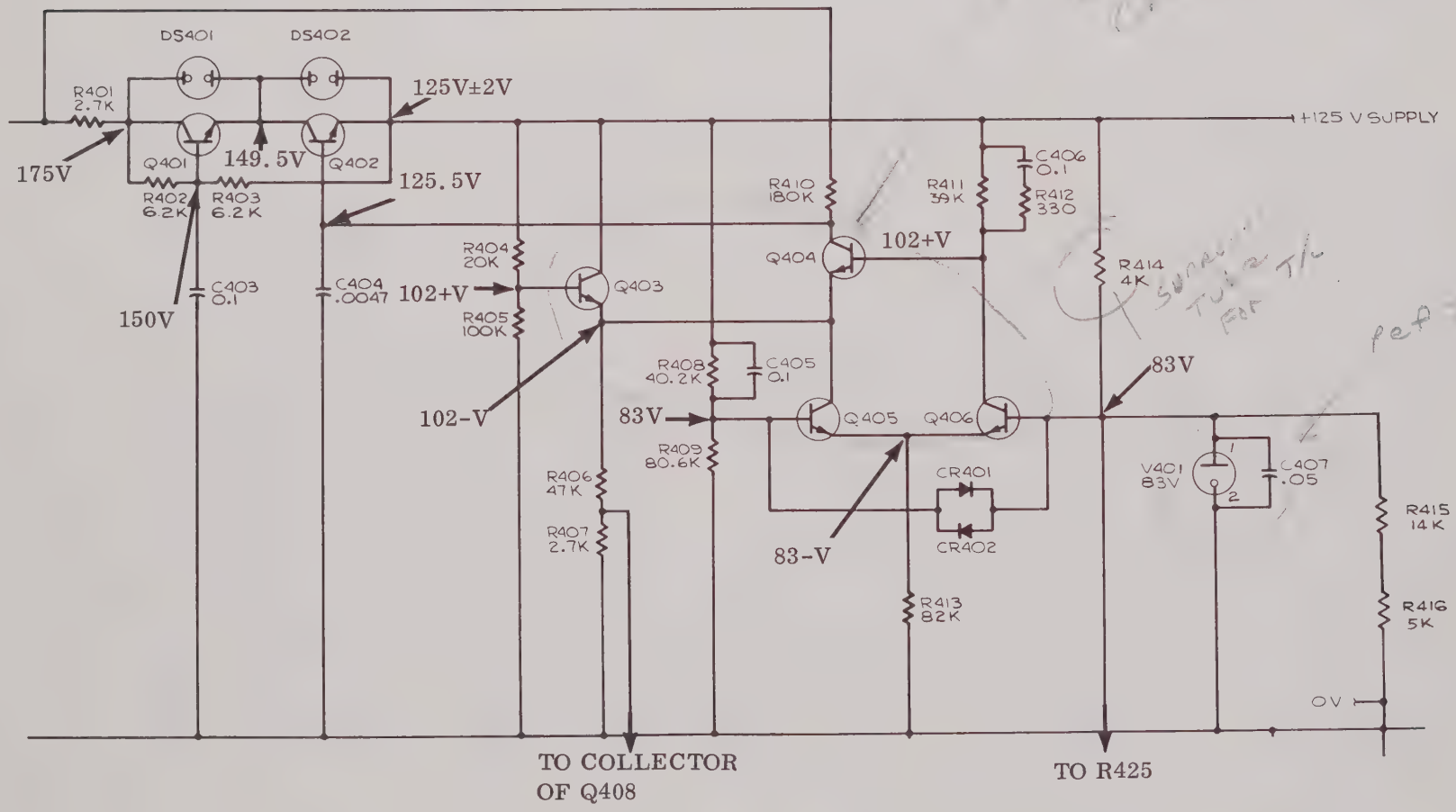
SO, $\frac{R_1 (E_{ref} - E_{sp} + E_{raw})}{R_1 + R_o} = E_{ref}$

$$R_1 E_{ref} - R_1 E_{sp} + R_1 E_{raw} = R_1 E_{ref} + R_o E_{ref}$$

$$R_1 E_{raw} - R_1 E_{sp} = R_o E_{ref}$$

$$R_1 (E_{raw} - E_{sp}) = R_o E_{ref}$$

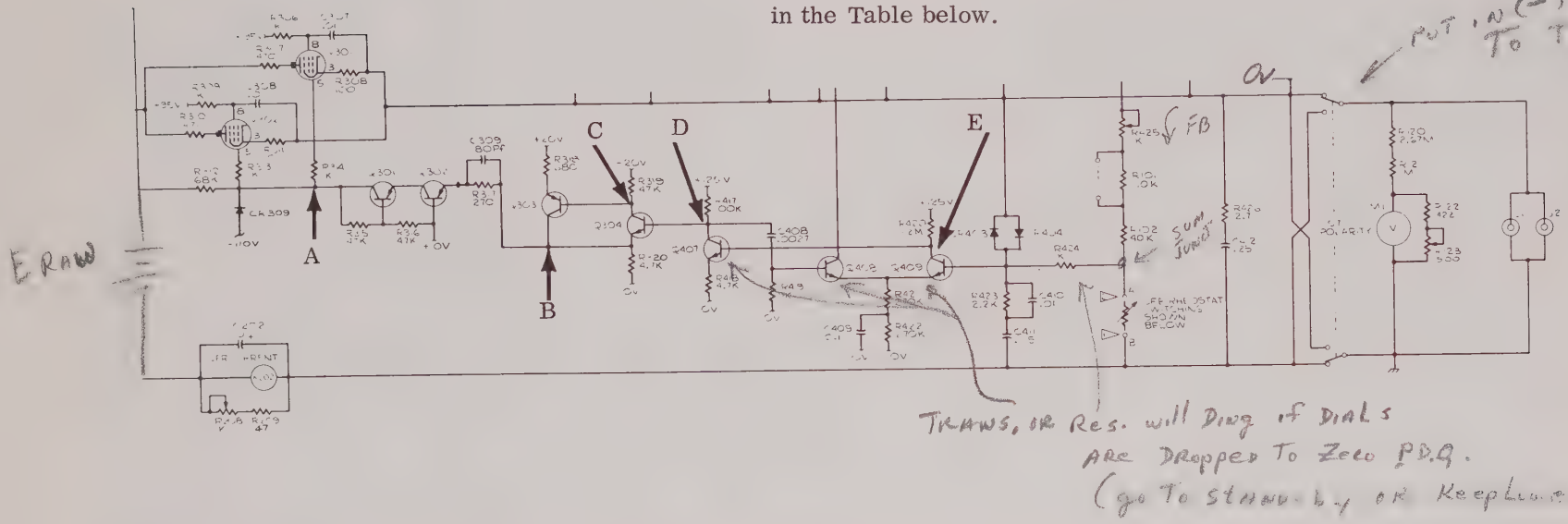
$$E_o = \frac{R_o E_{ref}}{R_1}$$


DS401
DS402
R401
2.7K
125V±2V
+125 V SUPPLY
175V
Q401
149.5V
Q402
125.5V
R402
6.2K
R403
6.2K
150V
C403
0.1
C404
.0047
R404
20K
102+V
Q403
R405
100K
102-V
R410
180K
Q404
102+V
R411
39K
C406
0.1
R412
330
R414
4K
R408
40.2K
C405
0.1
83V
83V
Q405
Q406
R409
80.6K
R406
47K
R407
2.7K
CR401
CR402
83-V
R413
82K
V401
83V
C407
.05
R415
14K
R416
5K
0V
TO COLLECTOR
OF Q408
TO R425

MOD. 405 - 408

Conditions of Measurement

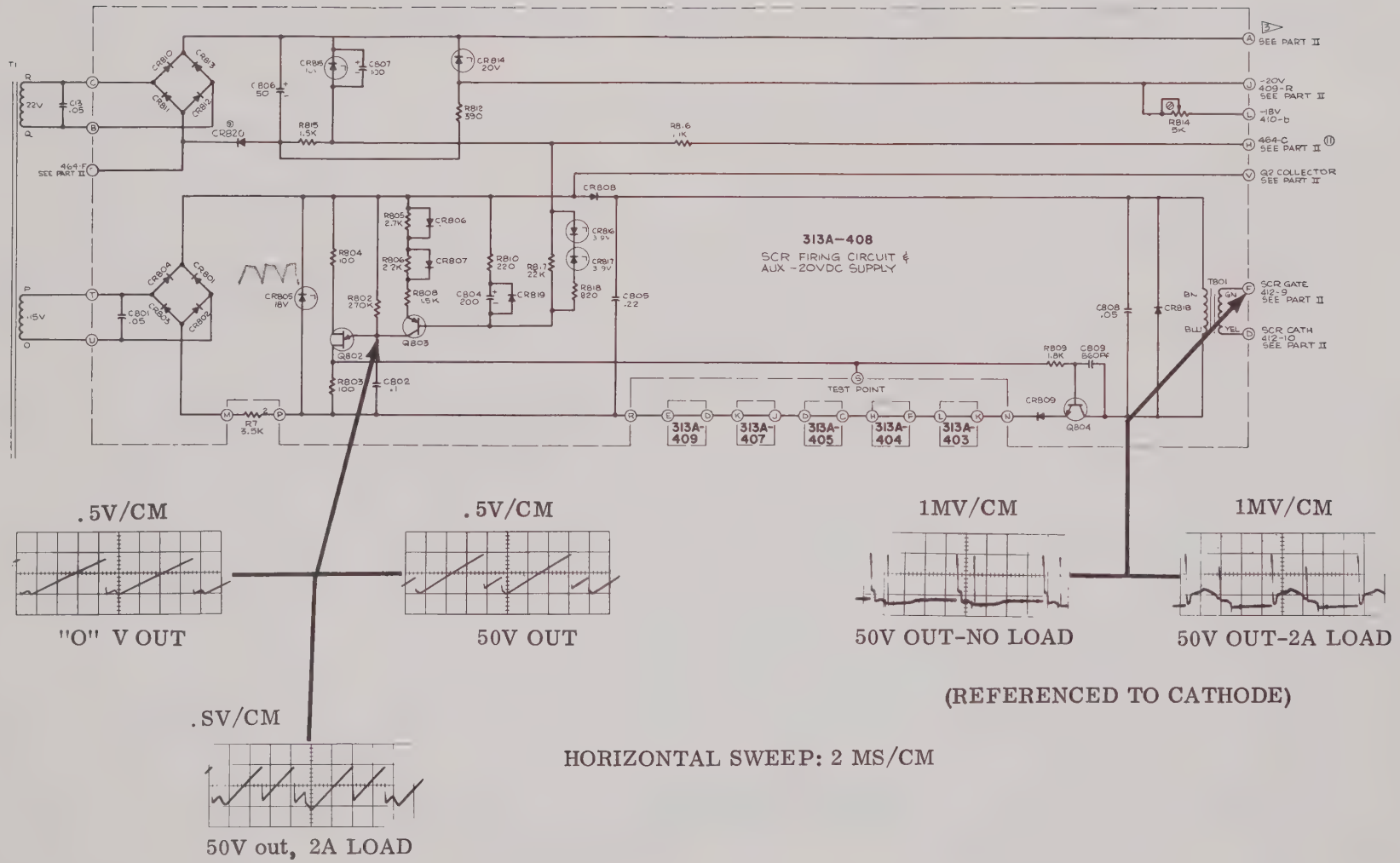
Series Pass Tubes Removed.
Unit "ON", Positive Polarity, "STANDBY" mode.
Connect a Mercury battery to Output Connector. Pos. to Pos., and Neg. to Connector Shell(chassis).
Connect a Differential Voltmeter to the elements indicated in the Table below.

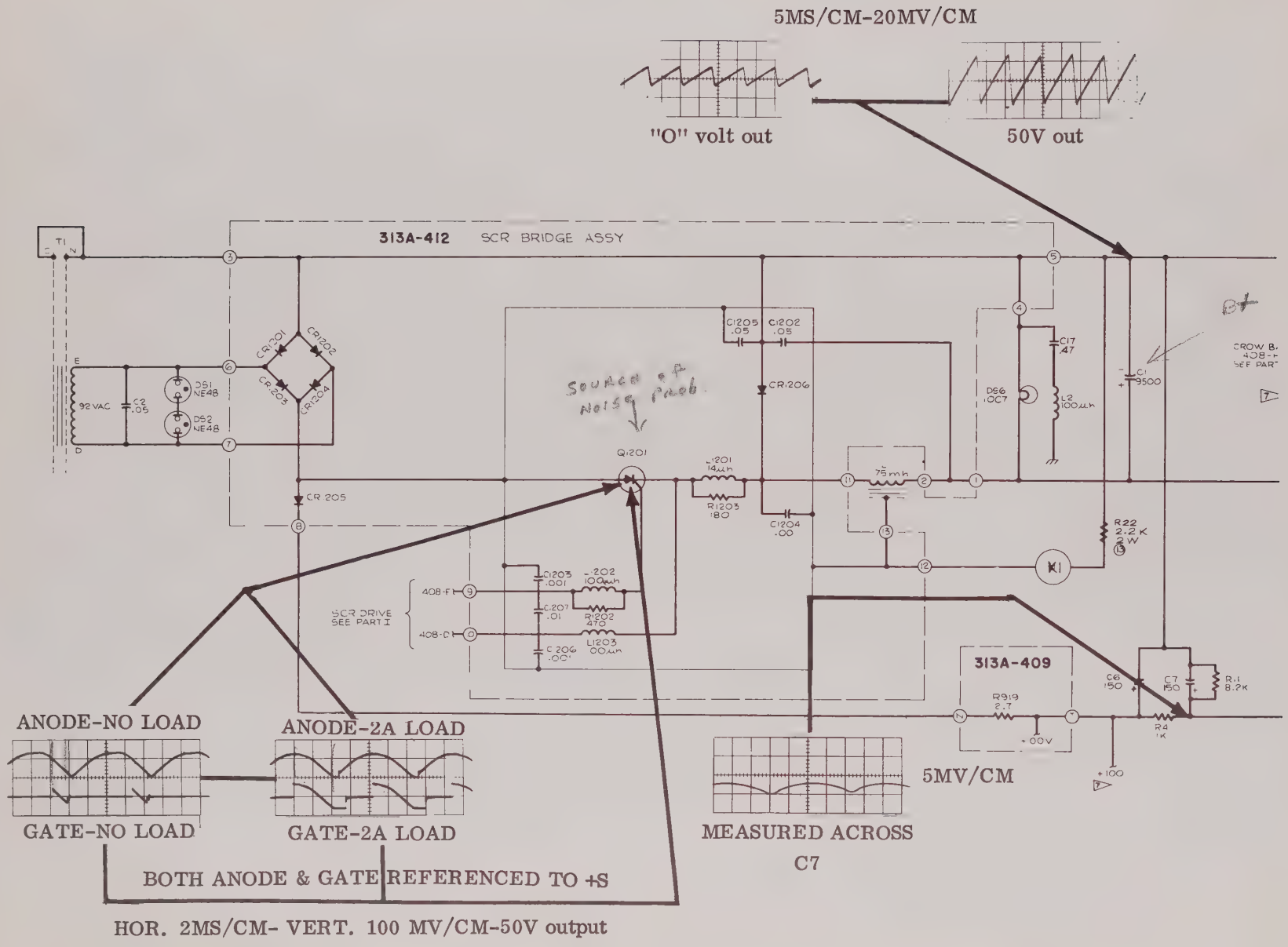


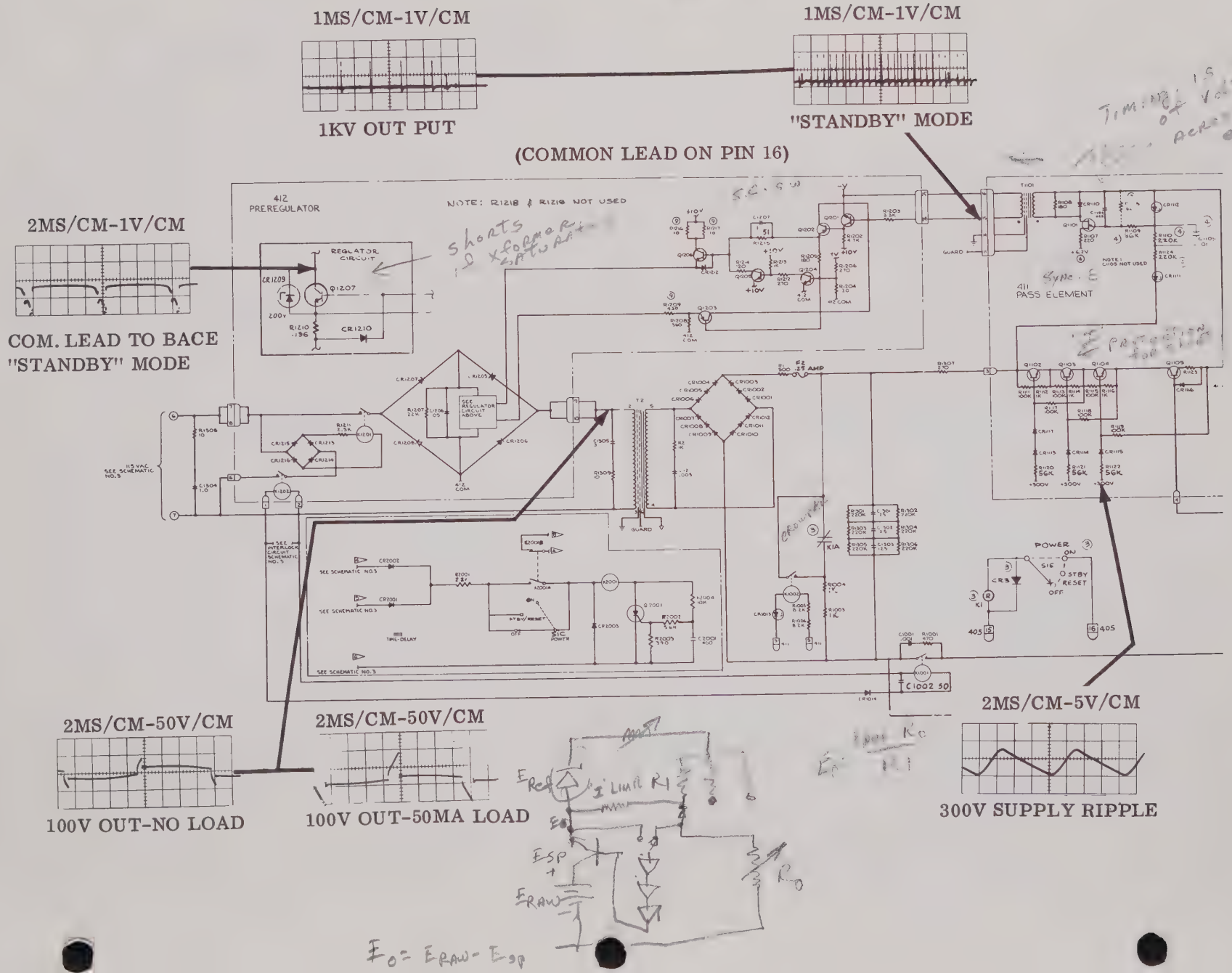
With a differential Voltmeter(883, or equiv.) referenced to the + Output, read the following voltages at the indicated points on the schematic.

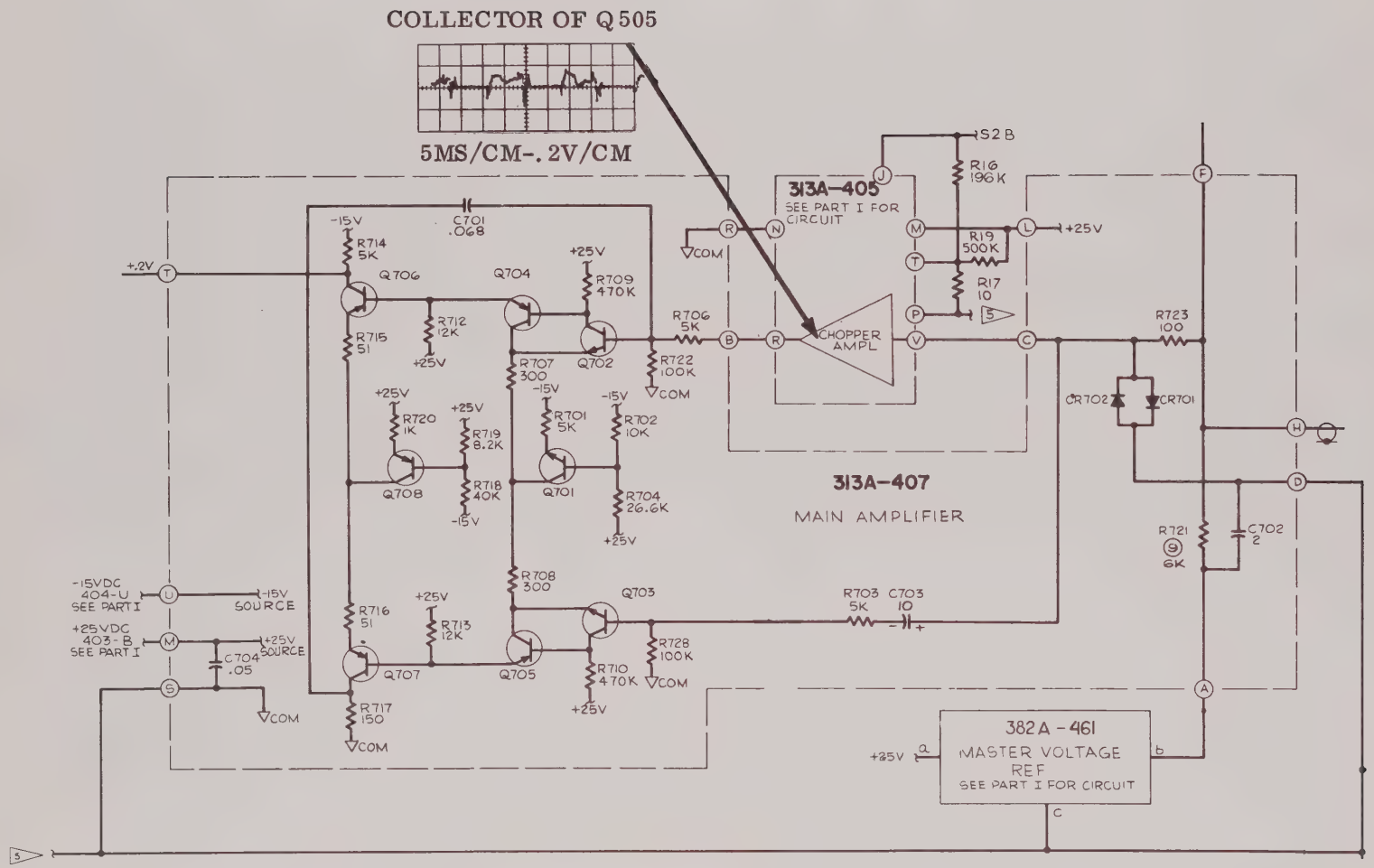
Dialed Voltage	Point "A"	Point "B"	Point "C"	Point "D"	Point "E"
1V	-100V	+6V	+18.5V	+6.6V	+7.1V
2V	+9.5V	+13V	+13V	+13.6V	-.14V

MIC 313 A


313A-408
SCR FIRING CIRCUIT &
AUX -20VDC SUPPLY
SEE PART II
-20V 409-R SEE PART II
+18V 410-b
464-C SEE PART II
Q2 COLLECTOR SEE PART II
SCR GATE 412-9 SEE PART II
SCR CATH 412-10 SEE PART II
TEST POINT
313A-409
313A-407
313A-405
313A-404
313A-403
.5V/CM
"O" V OUT
.5V/CM
50V OUT
1MV/CM
50V OUT-NO LOAD
1MV/CM
50V OUT-2A LOAD
(REFERENCED TO CATHODE)
.5V/CM
50V out, 2A LOAD
HORIZONTAL SWEEP: 2 MS/CM


5MS/CM-20MV/CM
"O" volt out
50V out
313A-412 SCR BRIDGE ASSY
T1
92 VAC
C2 .05
DS1 NE48
DS2 NE48
CR1201
CR1202
CR1203
CR1204
CR 205
CR 206
C1205 .05
C1202 .05
C17 .47
C1 9500
DS6 .007
L2 100μh
Q1201
L1201 14μh
R1203 180
C1204 .00
75mh
K1
R22 2.2K 2W
C1203 .001
L202 100μh
C207 .01
R1202 470
L1203 00μh
C 206 .001
408-F
408-D
SCR DRIVE SEE PART I
source of Noise Prob.
313A-409
R919 2.7
+100V
C6 150
C7 150
R1 8.2K
R4 1K
+100
5MV/CM
ANODE-NO LOAD
ANODE-2A LOAD
GATE-NO LOAD
GATE-2A LOAD
MEASURED ACROSS C7
BOTH ANODE & GATE REFERENCED TO +S
HOR. 2MS/CM- VERT. 100 MV/CM-50V output


1MS/CM-1V/CM
1KV OUT PUT
1MS/CM-1V/CM
"STANDBY" MODE
(COMMON LEAD ON PIN 16)
2MS/CM-1V/CM
COM. LEAD TO BACE
"STANDBY" MODE
412
PREREGULATOR
NOTE: R1218 & R1219 NOT USED
REGULATOR CIRCUIT
411
PASS ELEMENT
2MS/CM-50V/CM
100V OUT-NO LOAD
2MS/CM-50V/CM
100V OUT-50MA LOAD
2MS/CM-5V/CM
300V SUPPLY RIPPLE
POWER
ON
STBY
RESET
OFF
SEE SCHEMATIC NO.3
SEE SCHEMATIC NO.5
115 VAC

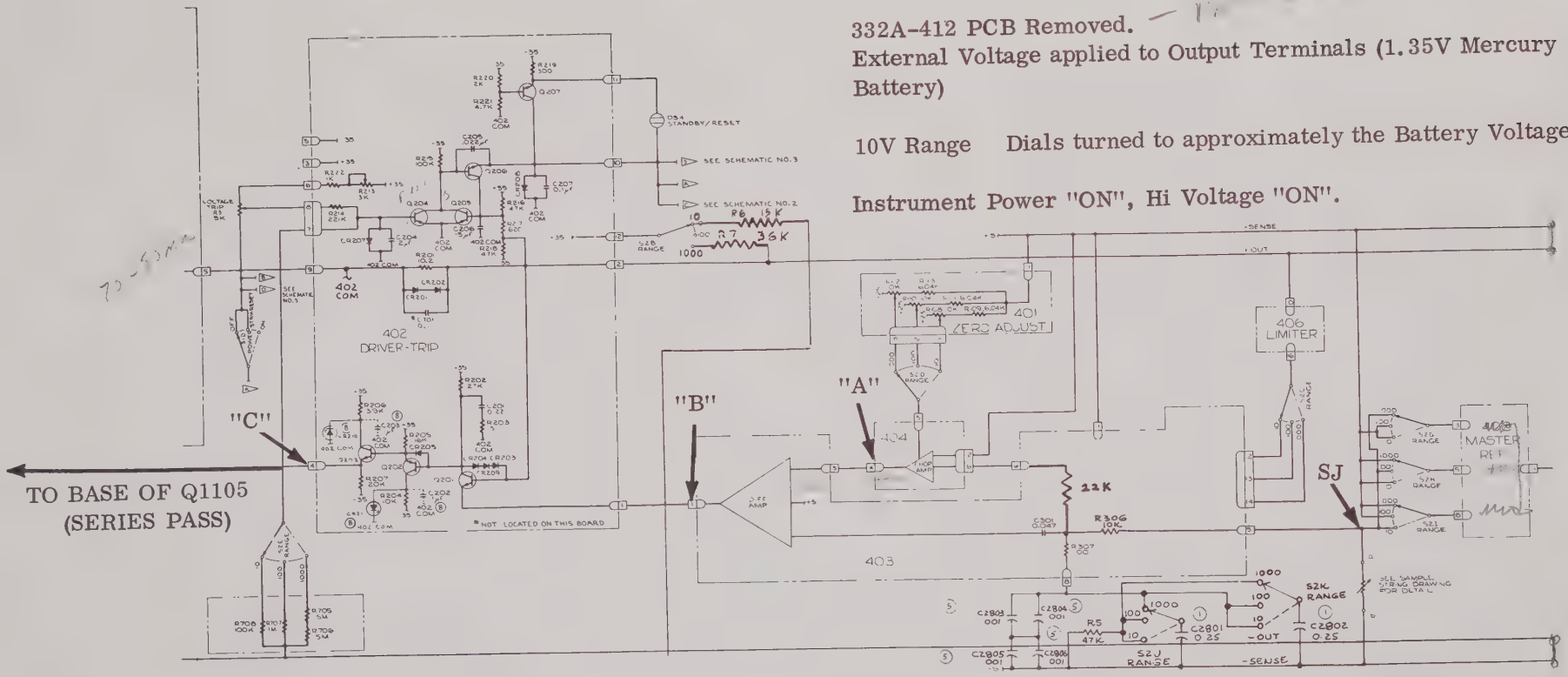

COLLECTOR OF Q505
5MS/CM-.2V/CM
313A-405
SEE PART I FOR CIRCUIT
313A-407
MAIN AMPLIFIER
CHOPPER AMPL
382A-461
MASTER VOLTAGE REF
SEE PART I FOR CIRCUIT
-15VDC 404-U SEE PART I
+25VDC 403-B SEE PART I
-15V SOURCE
+25V SOURCE
+.2V
-15V
+25V
COM
S2B
R16 196K
R19 500K
R17 10
R723 100
R721 6K
C702 2
CR702
CR701
C701 .068
R714 5K
R715 51
R712 12K
R709 470K
R707 300
R722 100K
R706 5K
R720 1K
R719 8.2K
R718 40K
R701 5K
R702 10K
R704 26.6K
R708 300
R716 51
R713 12K
R717 150
R710 470K
R728 100K
R703 5K
C703 10
C704 .05
Q706
Q704
Q702
Q708
Q701
Q707
Q705
Q703

CONDITIONS OF MEASUREMENT

332A-412 PCB Removed.
External Voltage applied to Output Terminals (1.35V Mercury Battery)

10V Range Dials turned to approximately the Battery Voltage.

Instrument Power "ON", Hi Voltage "ON".



With a Differential Voltmeter referenced to the + Output read the following voltages at the indicated points on the schematic:

DIALED VOLTAGE	POINT "A"	POINT "B"	POINT "C"
1.000000	+0.1V	-0.7V	-0.6V
2.000000	-0.44V	+2.0V (3.3 Rev)	+0.7V

332A Decimal Lamps burned out
Because of unfiltered DC

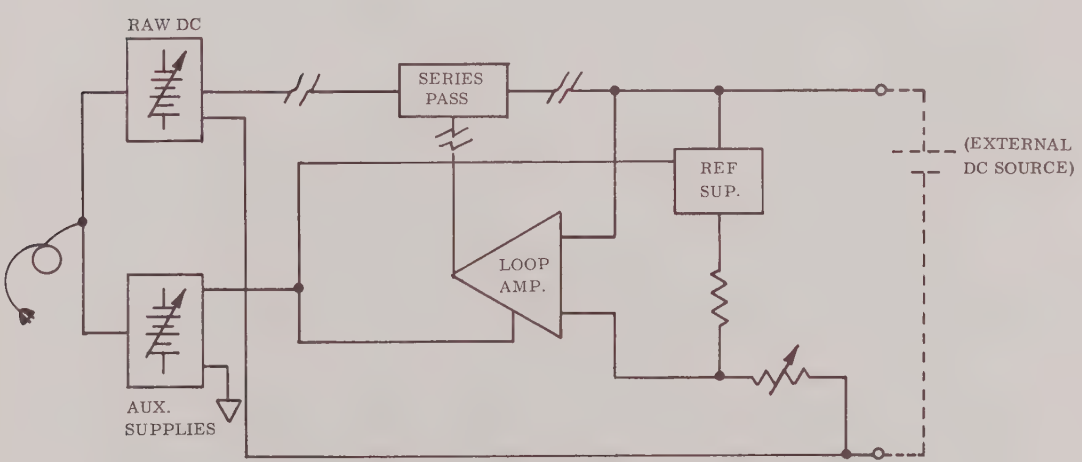
If conditions are met
Trouble in Pass Element
or Pre-Reg.

CHECKOUT PROCEDURE FOR POWER SUPPLIES

Any high voltage power supply can be split off into its individual block entities so that each block may be examined for proper operation before all of them are combined to constitute an entire instrument.

The proper procedure for checking any power supply should follow the guidelines listed below.

1) Disable the series pass element (s) by removal or circuit disconnection.
2) Check all auxiliary supplies for proper output voltage, stability, and ripple content.
3) Monitor the Referencesection of the instrument (Zener, or separate power supply) for the same parameters as indicated in step 2, except that the checking should be much more stringent.
4) Perform a Loop Amplifier check of the instrument to insure that it will regulate properly when provided with an error signal.
5) Check the raw DC section of the unit for appropriate levels of voltage. For those instruments that have Pre-regulators in the raw DC section, it will be necessary to check out the associated control ciruitry.



Only after it can be shown that each block entity is working properly should they all be put together and called an "operable" Power Supply. There is no guarantee at this point whether or not the instrument will meet all of its E_o specifications, but at least it should be able to be turned on to produce an E_o without catastrophic failure.

RELATING POWER SUPPLY ANALYSIS TO APPLICATION SYMPTOMS

1. Developing the symptom.

   a) Is it so catastrophic that the instrument is inoperable? If so, go directly to Loop Analysis.

   b) Is the instrument operable, but on a marginal basis? If so, operate it in as many settings as possible (Range, Dialed Output, etc.) to determine complete symptom description.

   c) Is the instrument generally operable, except for a particular area that is deemed to out of the ordinary? (e.g. a point out of tolerance, slightly high ripple, limiting controls borderline, etc.)

2. Relating symptom to simplified block diagram of any power supply.

   a) Catastrophic failures are usually related to the raw Hi Voltage section of the instrument.

   b) As long as the instrument is operable, the field broadens as to the actual block area of the instrument at fault. However, a simple "rule of thumb" is that:

      If the symptom is one where the front panel controls have little, or no, response ---- the problem most likely will be associated with the Loop Amplifier.

      If the problem is associated with a marginal spec, it may be well to consider the elements around the amplifier, such as the Reference Supply, R_1, or R_0.

3. Isolating the problem area of the instrument.

   a) Disable the supply's ability to allow hi voltage at the output in any form.

      Pull series pass element

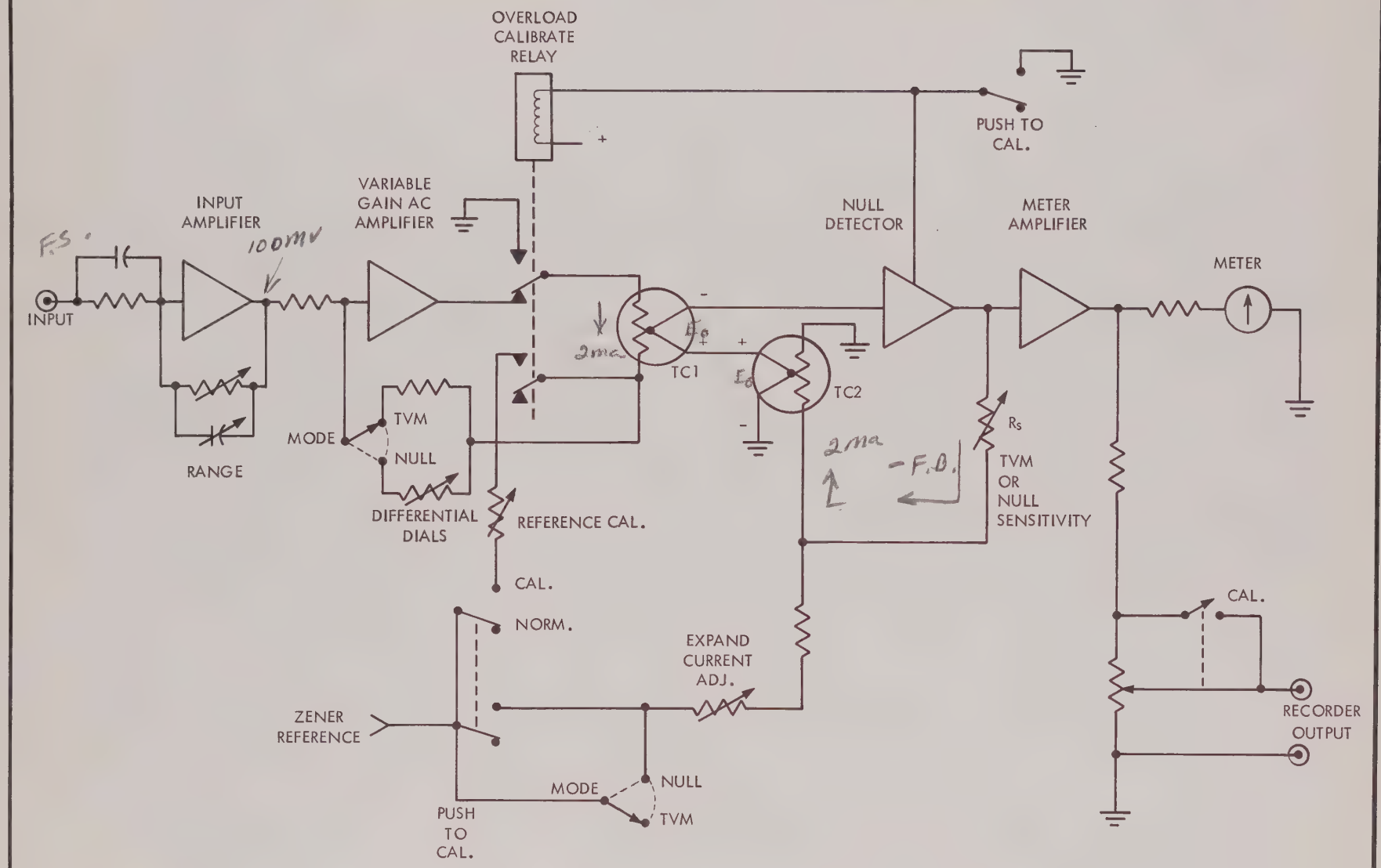
      Pull pre-regulator PCB (332 type supply)

   b) Check all auxiliary supplies for proper operating condition; nominal voltage, stability, etc.

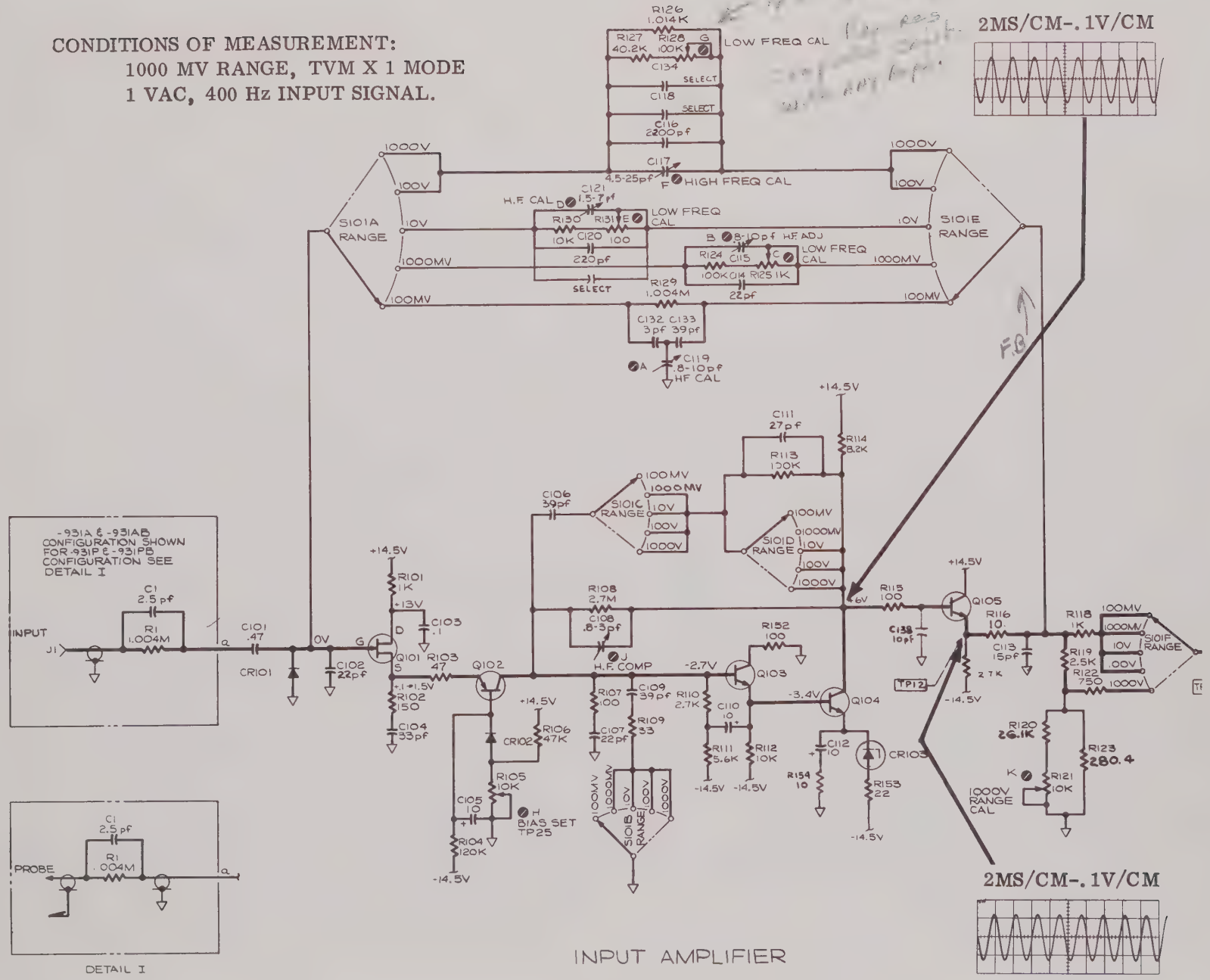
   c) Check raw DC section in and of itself to see if it will be sufficient to supply any desired output. If it has preliminary controls, it is also possible to check these.

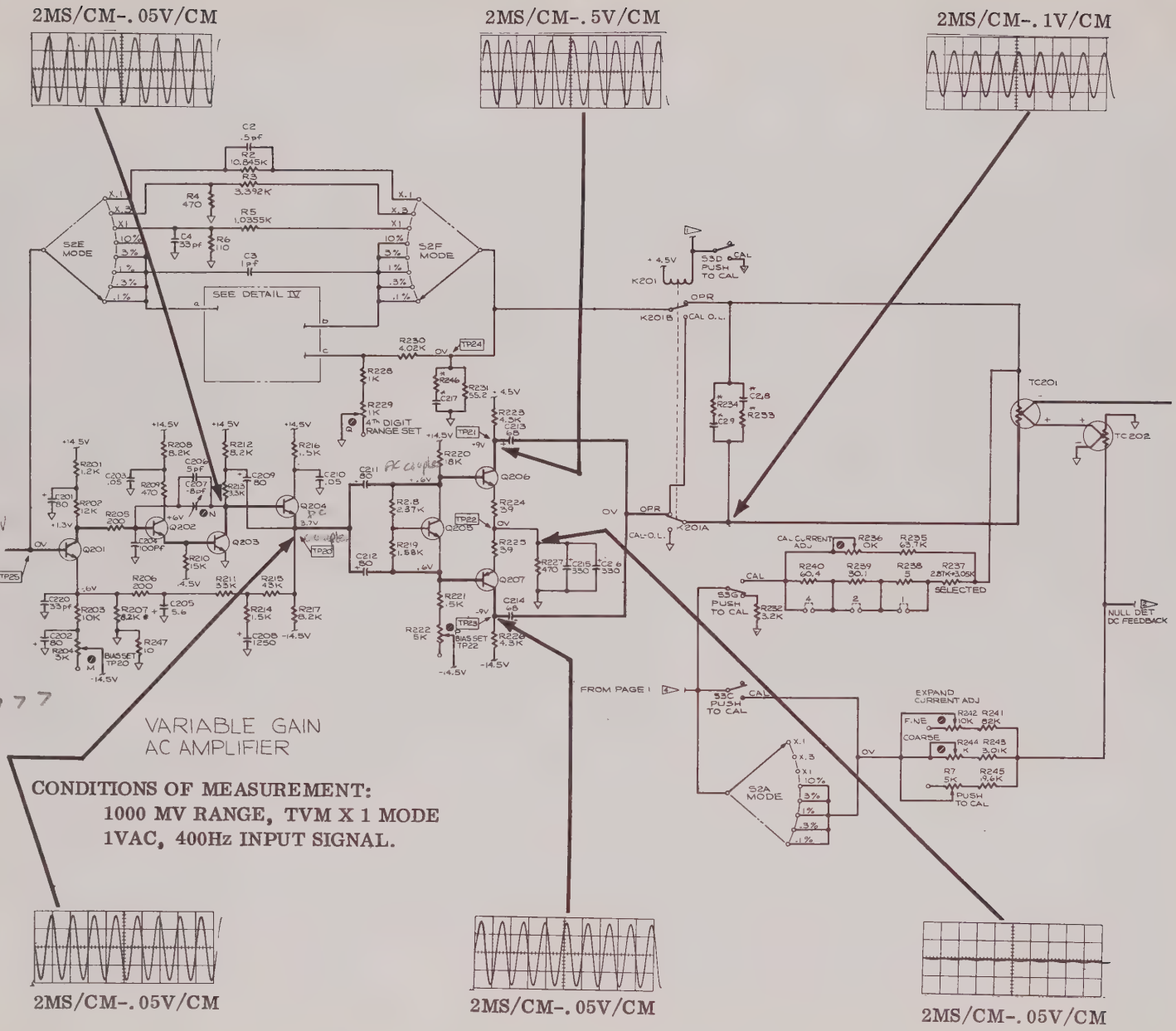
   d) Check the Reference Supply as a separate entity to see that it will properly reflect on the output voltage. Note that in the formula for power supply operation, output voltage is directly proportional to the Reference voltage. ($E_o = R_o/R_1 \times E_{Ref}$)

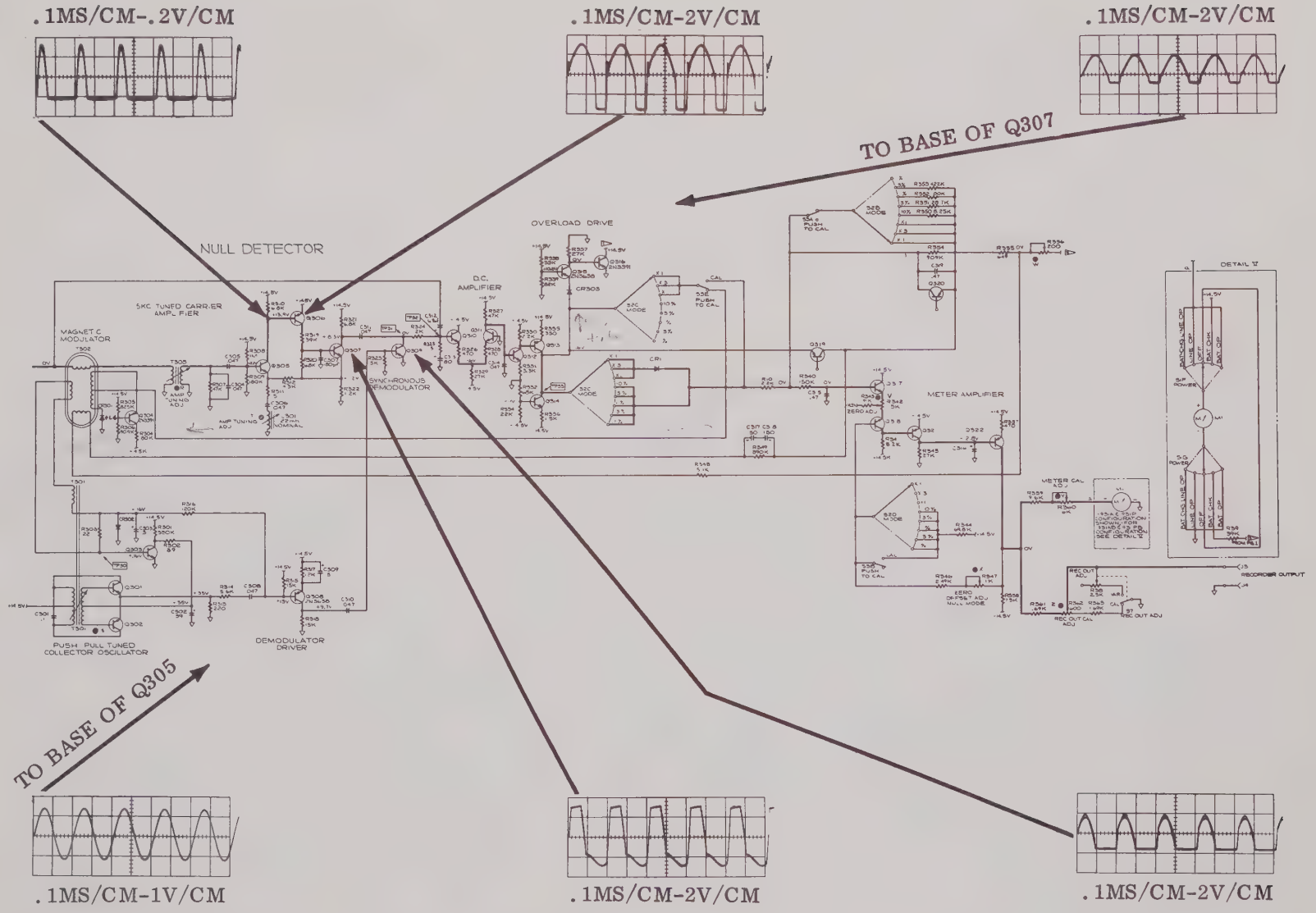
   e) Check the Loop Amplifier for proper operation. The same technique that is applied to the Calibration Power Supplies is also suitable for the Nuclear type supplies.


931 A
OVERLOAD CALIBRATE RELAY
PUSH TO CAL.
INPUT AMPLIFIER
VARIABLE GAIN AC AMPLIFIER
NULL DETECTOR
METER AMPLIFIER
METER
F.S.
100mv
INPUT
RANGE
MODE
TVM
NULL
DIFFERENTIAL DIALS
REFERENCE CAL.
CAL.
NORM.
2ma
TC1
TC2
E_o
R_s
TVM OR NULL SENSITIVITY
2ma
-F.D.
EXPAND CURRENT ADJ.
ZENER REFERENCE
MODE
NULL
TVM
PUSH TO CAL.
CAL.
RECORDER OUTPUT

CONDITIONS OF MEASUREMENT:
1000 MV RANGE, TVM X 1 MODE
1 VAC, 400 Hz INPUT SIGNAL.




2MS/CM-.05V/CM
2MS/CM-.5V/CM
2MS/CM-.1V/CM
SEE DETAIL IV
S2E MODE
S2F MODE
S2A MODE
4TH DIGIT RANGE SET
S3D PUSH TO CAL
S3G PUSH TO CAL
S3C PUSH TO CAL
CAL-O.L.
CAL CURRENT ADJ
SELECTED
EXPAND CURRENT ADJ
FINE
COARSE
PUSH TO CAL
NULL DET DC FEEDBACK
FROM PAGE 1
BIAS SET TP20
BIAS SET TP22
VARIABLE GAIN AC AMPLIFIER
CONDITIONS OF MEASUREMENT:
1000 MV RANGE, TVM X 1 MODE
1VAC, 400Hz INPUT SIGNAL.
2MS/CM-.05V/CM
2MS/CM-.05V/CM
2MS/CM-.05V/CM



CONDITIONS OF MEASUREMENT:

TP32 AND TP33 SHORTED TO GROUND.

400 Hz INPUT SIGNAL AJUSTED FOR SIGNAL MAGNITUDE SHORT OF SATURATION.

INSTRUMENT IN 1000 MV RANGE, TVM X 1 MODE.

INTERROGATION OF MODEL 931A TRUE RMS VOLTMETER

Before attempting to turn the instrument on, set the Range Switch to 100 mv, the Mode Switch to TVM X1, and the digit switches to zero. All of the following questions should have an affirmative answer.

I. If the instrument is Battery powered, does the meter deflect to the left when switched to BATTERY CHECK?

   a) Is it in the region showing that the batteries have sufficient charge?

II. When the instrument is switched to the BATTERY OPERATE position does the meter fluctuate, and then return to zero?

   a) By listening closely, can you hear the 2.5 kHz frequency of the Null Detector oscillator?

   b) If a wire is inserted into the signal input terminal while held in the hand does the meter deflect upscale to the right?

III. Turn the first digit to "1", and switch the Mode Switch to the 10% null. Does the meter needle immediately pin to full scale left?

IV. Return the first digit to "0". Does the meter immediately swing to right full scale?

   a) Can you hear the overload relay chatter?

   b) Will the instrument return towards a null condition when the Vernier dial is adjusted to approximately 10%?

V. What happens when the PUSH TO CAL switch is depressed?

   a) Does the meter pin immediately to either end-scale?

   b) After a few moments, does the meter needle begin to fall towards zero?

   c) Does rotation of the PUSH TO CAL knob while still holding it depressed allow an adjustment to null?

If the above questions can all be answered in the affirmative, it can be shown that the instrument is basically operable from the Reference Supply via the Thermocouples completely thru to the metering circuit. Return the Mode Switch to TVM and apply a 100 mv, 400 Hz signal to the input terminal.

VII. Does the meter deflect full scale to the right?

VIII. Is it possible to null the input signal while progressively switching to more and more sensitive null positions?

   a) Is the null reading within specifications? (Check internal calibration).

   b) Does the reading remain stable if the front panel knobs are tapped with a screwdriver?

At this point it can be stated that the instrument is wholly operable on at least the 100 mv Range, and any symptom associated with the instrument must be of a more subtle nature. (e.g. a frequency response problem).

I. In order to perform all the functions required of the 853A, we have available several circuits which we switch into place as they are needed. The best way to gain an understanding of the 853A is to examine each of these circuits in general as a funcitional unit, show how these circuits can be interconnected to perform the desired measurement, and, finally, to examine each circuit in detail, in order to better understand how it does the job.

II. There are seven circuits in the 853A:

A. The power supply/battery charger

B. The voltage regulator/reference supply

C. The inverter/isolator

D. The null detector/voltmeter

E. The ac-dc converter

F. The decade potentiometer

G. The precision divider strings

H. The current shunts

The power supply/battery charger, Figure 1, consists of a step-down power transformer supplying full-wave rectified dc to charge the batteries (if the unit has rechargeable batteries), and tapped at a low voltage to supply one-half wave dc for the operation of the instrument. A pilot lamp is used as a ballast to reduce the sensitivity of the charging current to changes in the line voltage and to provide a visual indication that the batteries are actually being charged. A diode in series with the battery is back-biased whenever the 853A is operated from the line; it prevents discharge of the battery when not needed.

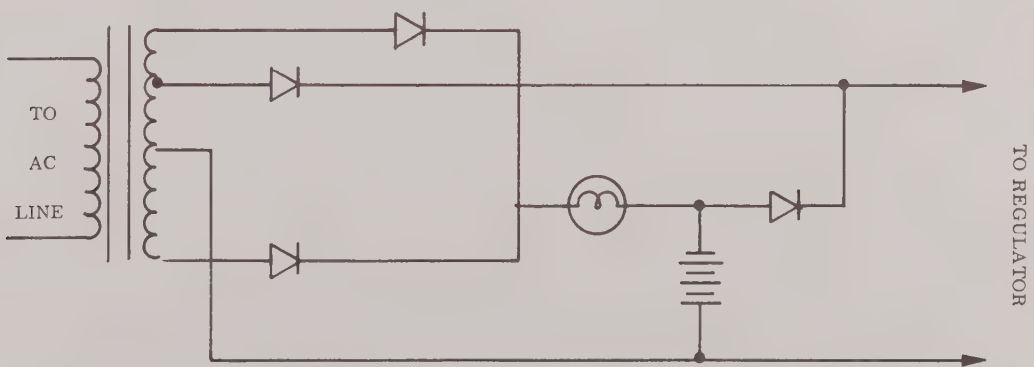


Figure 1. POWER SUPPLY/BATTERY CHARGER(Simplified)

The voltage regulator/reference supply, Figure 2, serves two distinct functions: it serves as a regulated, low impedance supply for the ac-dc converter, and it also serves as the voltage reference for the entire 853A. In order to conserve battery power, it is desirable to use the lowest possible voltage that will suffice for both needs. Since 10 volts in the lowest voltage that will operate the ac-dc converter satisfactorily, and operate the zener reference, this is the output voltage chosen.

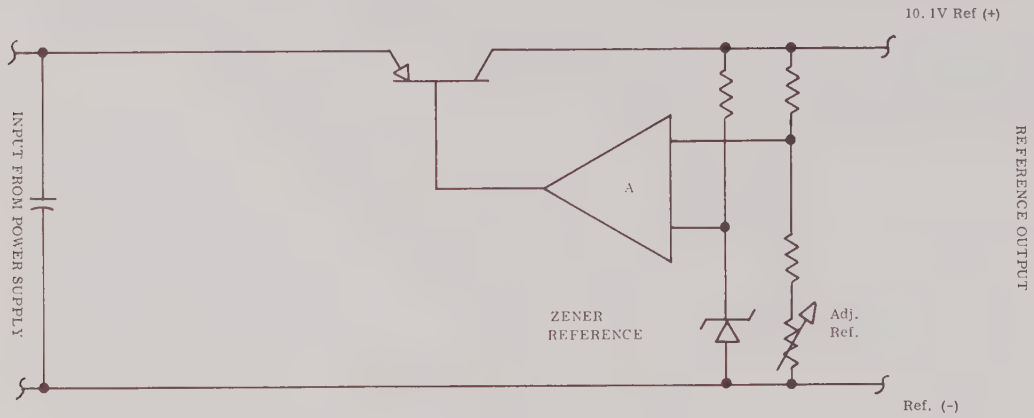


Figure 2. VOLTAGE REGULATOR/REFERENCE SUPPLY

The inverter/isolator (which also operates from the 10 volt regulator output), Figure 3, supplies all the voltages needed to operate the null detector/ voltmeter. The inverter is a transformer-coupled multivibrator operating at a constant frequency of 215 Hz. The squarewave voltage at the transformer secondary drives the null detector chopper and demodulator and it is also rectified to supply the B+ and B- operating voltages for the null detector.

The inverter also accomplishes the most crucial function of all -- it provides the essential dc isolation between the null detector and the rest of the 853A circuitry. Without the inverter/isolator, it would be necessary to provide another power supply winding and another set of batteries -- just to allow the floating operation of the null detector.

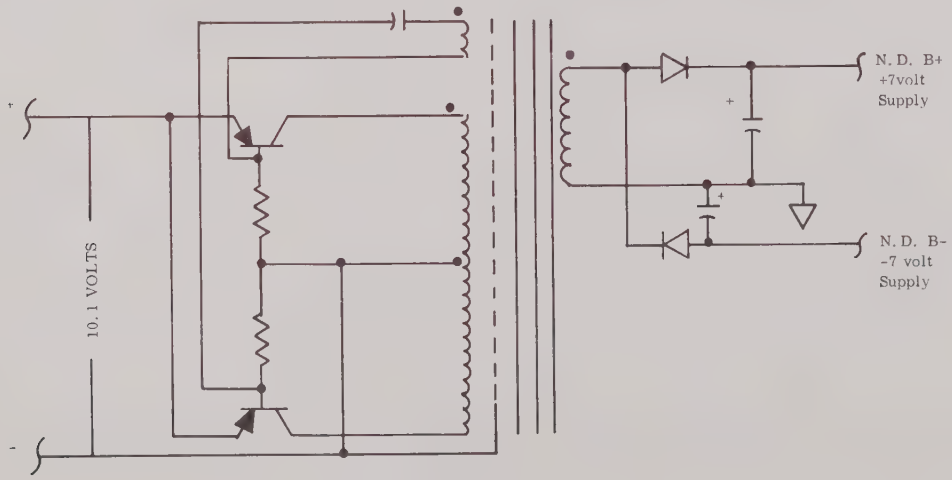


Figure 3. INVERTER/ISOLATOR

The null detector/voltmeter, Figure 4, is a chopper amplifier, using an insulated-gate FET as a chopper. It can be connected to serve as a high impedance voltmeter whose gain is closely controlled by negative feedback, or it can be connected as a sensitive null detector with variable gain controlled from the front panel of the 853A.

In the DIRECT mode, the DIFF/DIR switch shown in Figure 4 connects the appropriate negative feedback resistor (selected by the range switch) and also shorts out the variable gain pot to ensure the maximum possible loop gain for the most accurate readings. A pot in series with the meter calibrates its full-scale sensitivity.

In the DIFFERENTIAL mode, the switch opens the feedback loop, inserts the variable gain pot -- and also connects a resistor from the meter to the amplifier power supply to drive the pointer to mid-scale. This resistor is adjustable to allow exact centering.

As a null detector, the amplifier has an input impedance of approximately 4 Megohms and a maximum sensitivity of approximately ±600 uv for a ± full-scale reading. With the gain control turned to minimum, the gain is reduced by a factor of 100.

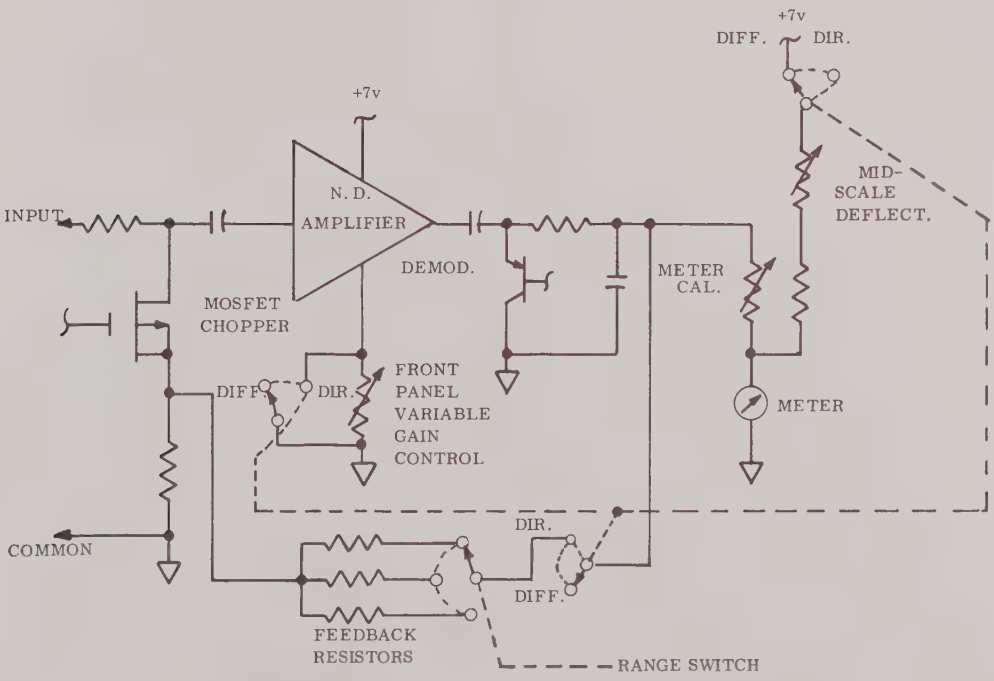


Figure 4. NULL DETECTOR/VOLTMETER (Simplified)

The ac-dc converter, Figure 5, is an ac coupled operational amplifier whose negative feedback signal is derived from the voltage drop caused when the output current flows through R_e. Provided the gain of the operational amplifier is very high, the voltage-to-current transfer ratio, $\frac{i_o}{e_{in}}$, is governed solely by the choice of R_1, R_f, and R_e.

It now remains to insert a fullwave rectifier in the output current path to recover a dc voltage proportional to the average value of the ac output current. This voltage can be developed by inserting a resistor in series with one of the rectifiers.

Since we usually desire to know the rms, rather than the average, value of the input voltage, the circuit resistances are chosen to yield an output dc voltage 1.11 times the average -- the ratio between the rms and average values of a sine wave.

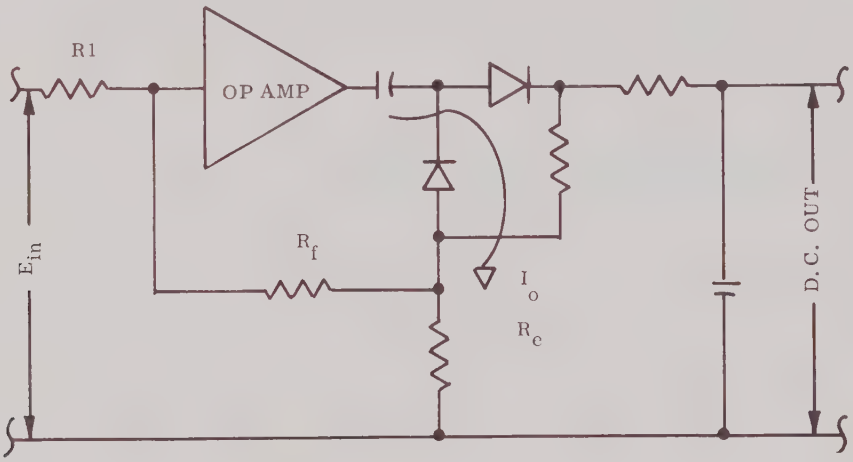


Figure 5. AC-DC CONVERTER

The decade potentiometer, Figure 6, is a constant resistance type known as a "put-and-take" divider. Unlike the Kelvin-Varley divider, it is a true potentiometer whose resistance from the tap to the lower end is equal to the total resistance from the tap to the upper end. Because of this feature, the lower portion can be used as a rheostat -- one of the arms of a Wheatstone Bridge. The total resistance of the divider is 11.1K ohms and the maximum setting of the dials is 1.1100, over-ranging on the first two dials.

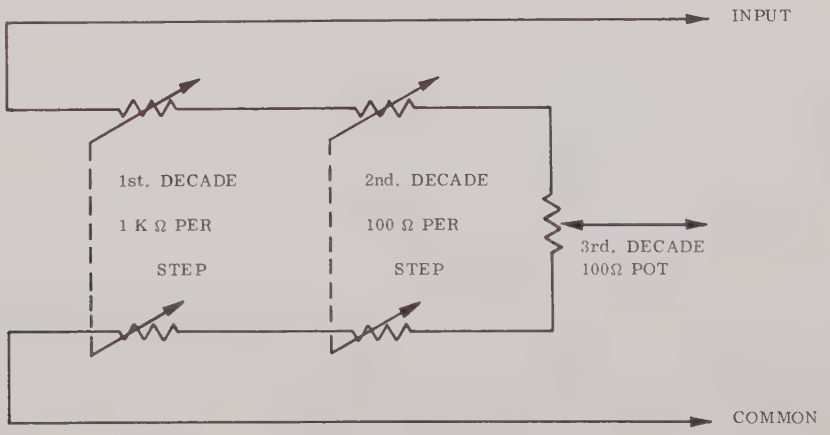
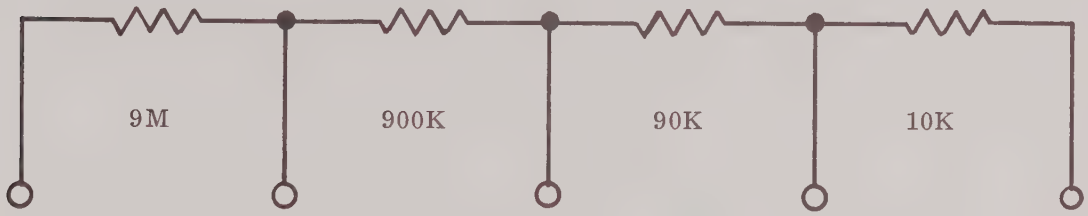


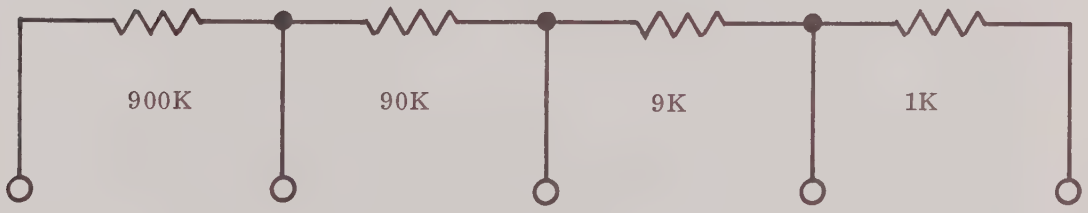
Figure 6. DECADE POTENTIOMETER

The precision divider strings, Figure 7, consist of two strings of decading resistors. The input string, Figure 7A, is a 10 Megohm string that divides down input dc voltages to approximately 1 volt full-scale. The reference string, Figure 7B, divides down the reference supply voltage to place the desired full-scale voltage at the top of the decade potentiometer.

All the divider resistors are grouped to match each other within ±200 ppm. It is upon their stability that the stability of the 853A depends.



A. INPUT STRING



B. REFERENCE STRING

Figure 7 PRECISION DIVIDER STRINGS

The current shunts, Figure 8, consist of five low inductance resistors matched to within ±200 ppm, and a separate 10A shunt which can be calibrated with the instrument. The drop across these shunts at full scale is 100 mv. The four used in the highest ranges are true four-terminal resistors used to prevent the voltage drop across the leads from affecting the accuracy of the readings.

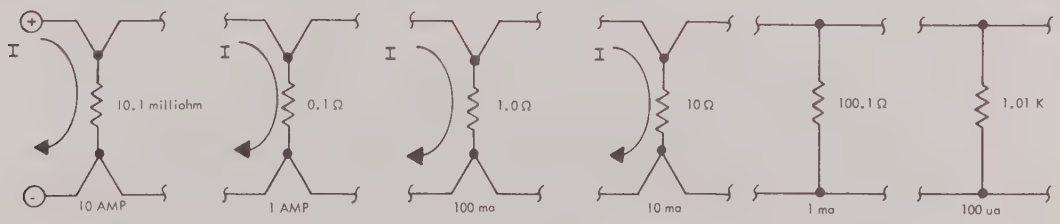


Figure 8. CURRENT SHUNTS

III. Now that you have had a general look at the "facilities" available in the 853A, let's see how these are connected together to obtain the various ranges and modes of operation.

NOTE: No attempt will be made in the ensuing sections to describe the function of each and every switch pole. Many of them are used only to avoid leakage currents, capacitive feed-through, voltage breakdown problems, etc., and their discussion would serve only to confuse matters.

First, we dispense with the power supply, voltage regulator/reference supply and inverter by noting that they are hooked together at all times. These three, plus the null detector and ac-dc converter amplifiers, are on the PCB.

3-1. DC VOLTAGE (See Figure 9)

When one of the four dc voltage ranges are used, the input divider string is connected across the input binding posts. The uppermost resistor is a 1 Megohm precision resistor used for isolation of the circuit under measurement. The rest of the resistors divide the input voltage by successive factors of ten so that the full-scale voltage at the selected tap will always be $\frac{10}{11}$ (0.9091 volts).

In direct reading mode, the voltmeter is connected across the output of the divider and a 1.02 K feedback resistor is connected to give a gain of $\frac{1}{0.9091}$, or 1 volt for a 0.9091 volt full-scale input. With this amount of negative feedback, the amplifier has an input impedance of approximately 3,000 Megohms and presents a negligible load to the input divider. For negative polarity voltages, we simply reverse the meter terminals.

To make a differential measurement, the amplifier is connected for use as a null detector, as described in Section II. The low side is connected to the decade potentiometer tap and the pot adjust for a null. The proper voltage is supplied to the pot through three of the four resistors of the reference divider string. The 853A is calibrated for dc voltage by adjusting the reference supply voltage around its nominal value at 10.1 volts.

For negative polarity readings, the meter is reversed, as in the direct reading case, and, in addition, the reference supply is reversed and the meter centering current is drawn from the null amplifier negative supply.

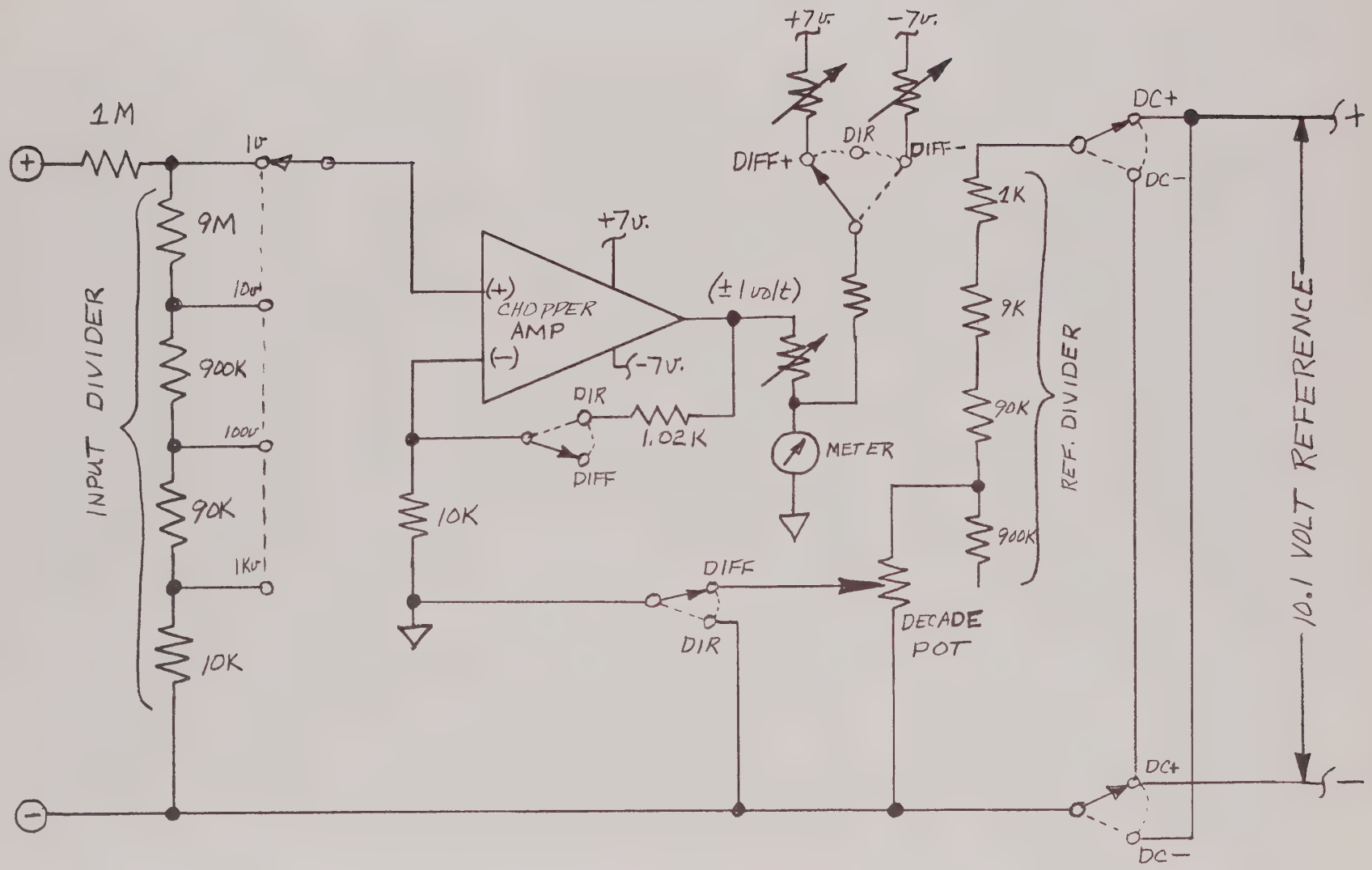


Figure 9. DC VOLTAGE CONNECTION

3-2. DC CURRENT (See Figure 10)

Instead of an input divider, as in the voltage case, dc currents are shunted through precision shunts (a little humor there). The voltage dropped across these shunts is what the 853A measures, in much the same way that voltage was measured. In the case of current, however, full-scale current develops only 100 mv! Observe the way the shunts are connected; there is a path for the current to travel through and a separate pair of terminals to sense the voltage drop. In this way, variations of lead length or switch contact resistance will not affect the accuracy of the shunt. In the case of the 10 amp range, the shunt is wired to a separate pair of binding posts since the switch wiring will not carry these currents.

Direct Mode is identical to the voltage case except that the feedback resistor is now 90.9 K to give a gain of ten.

In the differential mode, it is necessary to develop 100 mv on the potentiometer for full scale. To do this, an additional 900 K resistor is switched into the reference divider string. 900 K is slightly too much, however, and the total resistance must be lowered about 0.12%. This is fortunate--because there is a tolerance of ±1000 ppm on the resistance of the shunts, even though they are matched to ±200 ppm. We, therefore, shunt 10 K worth of the reference divider with a resistor selected to compensate the exact value of the shunts. In this way, it is not necessary to calibrate the 853A in current ranges except for the 10 amp range. An adjustment is provided for the 10 amp shunt for two reasons: (1) it is not economic to make this shunt to a tolerance of 0.1% as the others are, and (2) there is no over-load protection for the 10 amp range and the adjustment provides a way of recalibrating after excessive brutality.

The sharp-eyed will have noted a 100 K resistor that shunts the shunts (more humor?) in each current range. The two highest value shunts have been slightly increased to allow for this load. This 100 K resistor is a substitute for the 100 K load resistance which the shunts must see in ac current ranges. It makes uniform calibration possible.

In all other respects, dc current parallels dc voltage: same null detector hook-up, same polarity reversal, etc.

3-3. AC VOLTAGE (See Figure 11)

To measure an ac voltage, it is converted to dc, 0.9091 volts full-scale, by the ac-dc converter and then measured exactly as if it was a dc voltage coming from the input divider string. It is as simple as that. It remains only to examine the details of ac-dc conversion. Refer to the description of the converter in Section II.

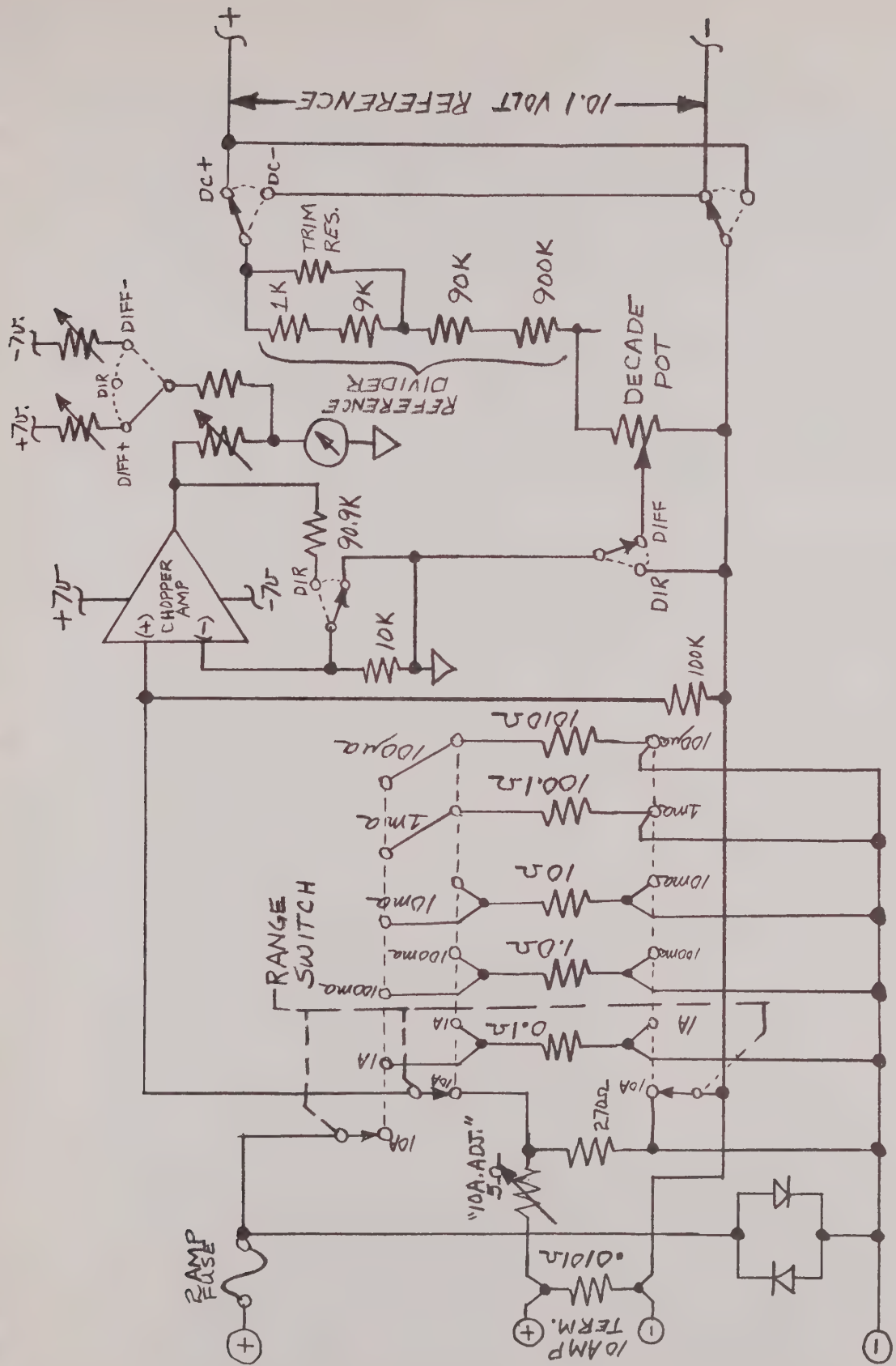


Figure 10. DC CURRENT RANGES

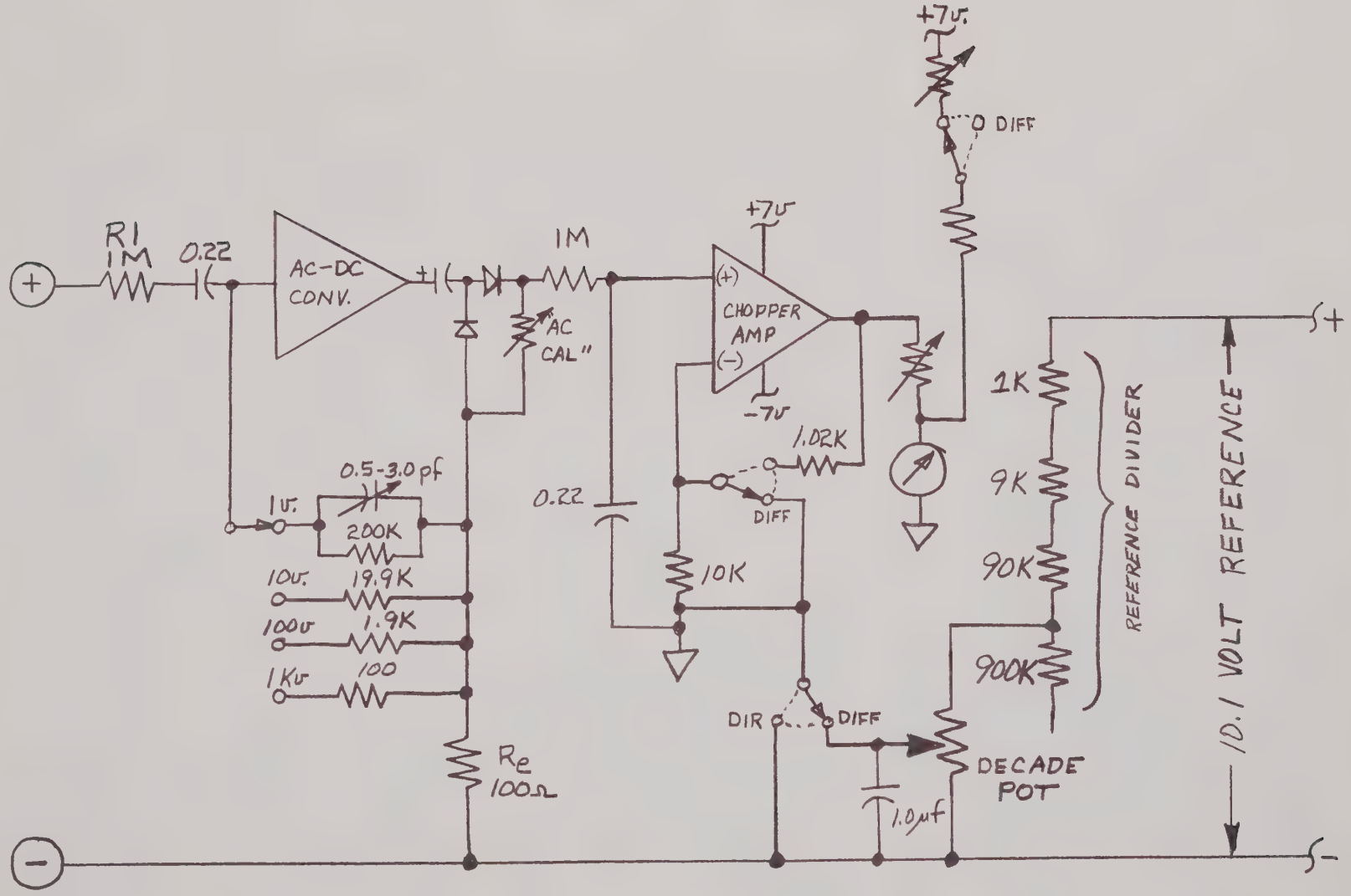


Figure 11. AC VOLTAGE RANGES

The input resistor, R1, is the same one that served as the input divider isolation resistance (See Figure 9). A 0.22 uf Mylar capacitor keeps dc out of the circuit. The four resistors, R_f, are range-changing negative feedback resistors, tightly matched so that it is only necessary to calibrate one range with the ac calibrate pot, and the others will follow. The trimmer capacitor across R_f is adjusted for a flat HF response; it is needed on only the 1 volt range, due to the high resistances involved.

3-4. AC CURRENT (See Figure 12)

The converter output is the same on ac current as on ac voltage, i.e., 0.9091 volts full-scale. The shunts are the same ones used for dc current. The only change is in the converter input resistance R_2: it is now 100K instead of 1 Megohm and the coupling capacitor is 2.2 uf instead of 0.22 uf. A trimpot, R_3, calibrates the sensitivity, and a trimmer capacitor adjusts the HF response.

You may have wondered why the input resistor was changed instead of one of the feedback resistors. It is necessary to keep the parallel resistance of R_2 and the feedback resistor well below 500K in order to preserve the loop gain of the converter. This is possible only if the input resistor is lowered.

3-5. RESISTANCE (See Figures 13, 14 and 15)

The ohms ranges are by far the most interesting part of the 853A. It will probably be more instructive to begin by discussing the differential operation.

DIFF ohms is a classic Wheatstone Bridge configuration (See Figure 13A). The decade potentiometer is connected as a rheostat and serves as the adjustable "R_Y" leg; the unknown is the "R_X" leg. The input divider string serves as one ratio arm, "R_A" and the reference divider string is the other ratio arm, "R_B." The reference supply serves for bridge power, and the null detector is connected between the opposite corners to detect bridge balance. The equation for bridge balance is

$$\frac{R_X}{R_Y} = \frac{R_A}{R_B}, \text{ or } R_X = R_Y \cdot \frac{R_A}{R_B}$$

Since R_A and R_B are closely grouped, the accuracy of the reading depends solely on the accuracy of R_Y, which is our precision potentiometer. R_Y has a resistance of 10K ohms for full scale. Therefore, it should be a simple matter to determine what R_A/R_B must be for each resistance range A suitable R_A and R_B can then be selected from the rather limited assortment available. The table, Figure 14A, shows the values chosen for each range. Also shown is the full-scale voltage across R_X, the short circuit current and the maximum possible dissipation on that range for any value of resistance. The graph, Figure 14B, shows the measured sensitivity of the bridge in each range.

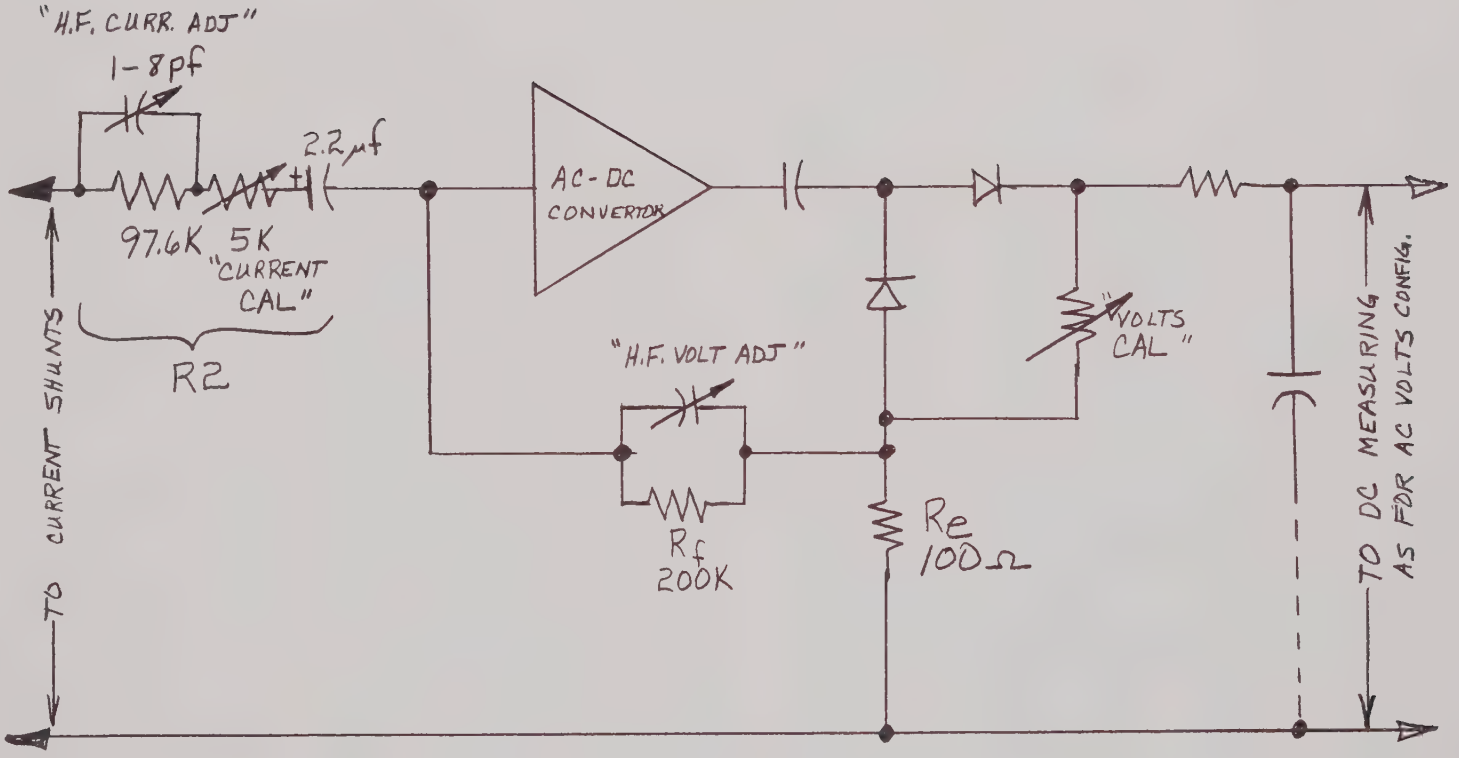


Figure 12. AC CURRENT RANGES

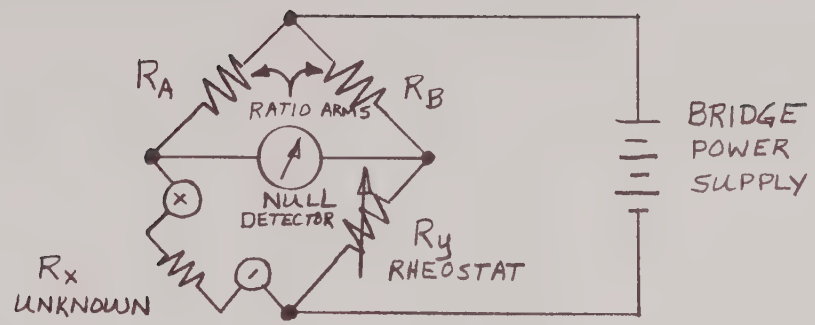


Figure 13A. WHEATSTONE BRIDGE

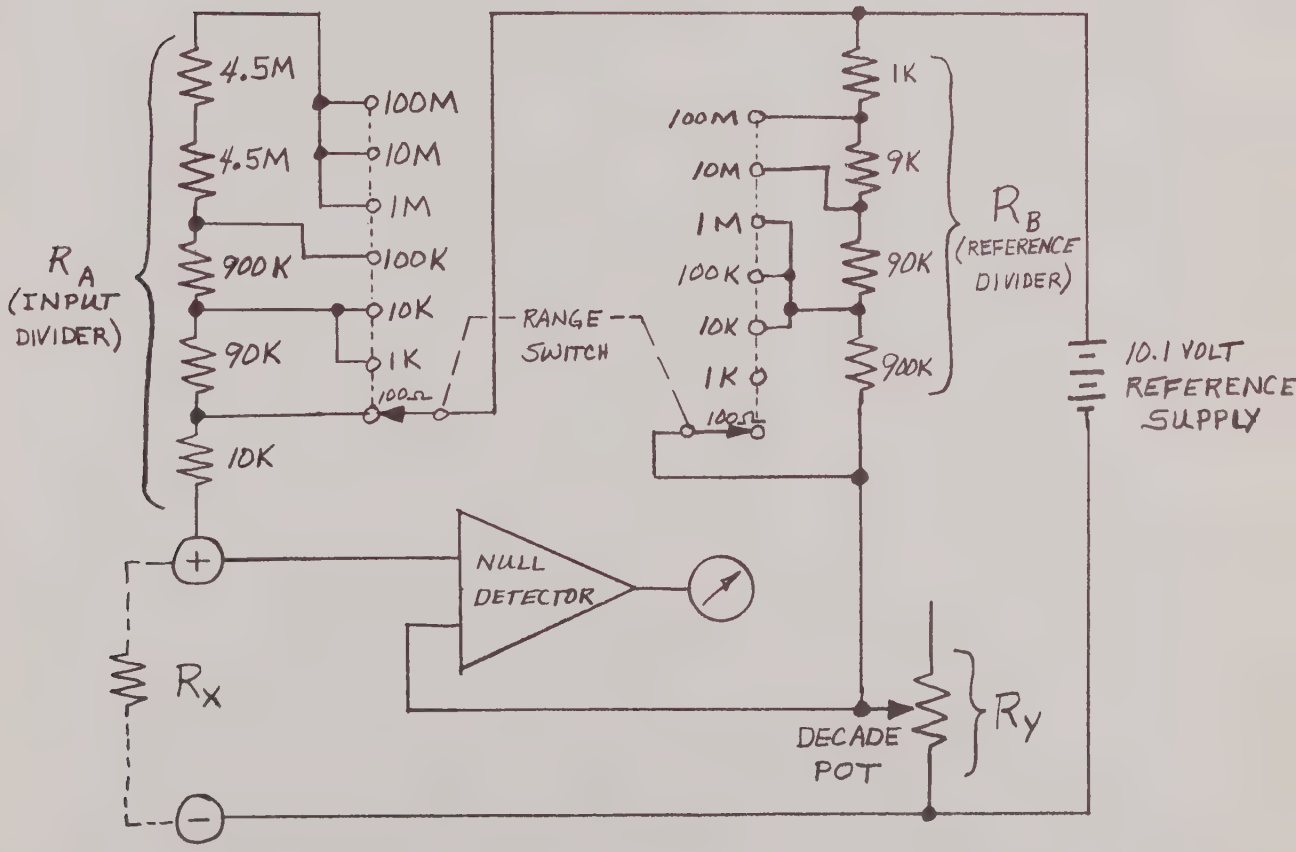


FIGURE 13B. DIFF OHMS CONNECTION

RANGE (R_X)	$\frac{R_A}{R_B}$	R_A	R_B	$V_{FULL-SCALE}$	$I_{MAXIMUM}$	$P_{DISSIPATION}$ (Maximum)
100 ohms	.01	10 K	1 M	0.1	1 ma	2.5 mw
1 K	0.1	100 K	1 M	0.1	100 ua	.25 mw
10 K	1	100 K	100 K	1	100 ua	.25 mw
100 K	10	1 M	100 K	1	10 ua	25 uw
1 M	100	10 M	100 K	1	1 ua	2.5 uw
10 M	1000	10 M	10 K	5	1 ua	2.5 uw
100 M	10,000	10 M	1 K	9	1 ua	2.5 uw

FIGURE 14*a*. WHEATSTONE BRIDGE PARAMETERS

(See Diagram, Figure 13B)

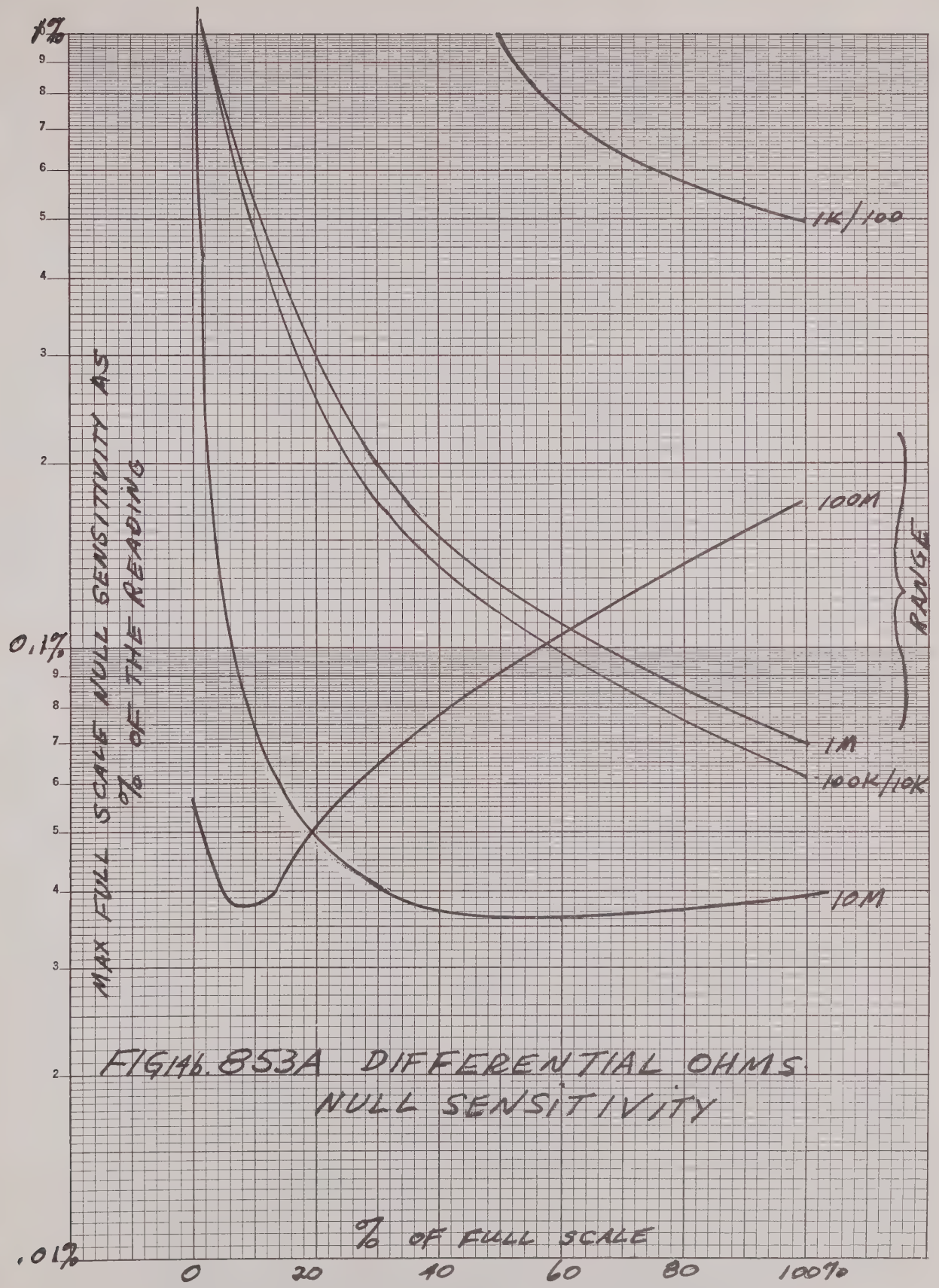


FIG146.853A DIFFERENTIAL OHMS NULL SENSITIVITY

Figure 4b.

DIR OHMS is quite another problem. To obtain a linear deflection a constant current is driven through the unknown resistance and the resulting voltage drop is measured by the voltmeter. Figure 15A shows how it is done, figuratively speaking.

But where to obtain a constant current? The 100 ohm and 1K ranges already have a reasonably constant current in the form of R_A which is 100 times as large as the unknown (See Figure 15B). The worst possible error due to the slight change of current will be only 0.5% of full scale if we are "on" full scale. So these ranges are easily taken care of. But the 100K range is not so obliging; R_A is still 100K, but it doesn't look like much of a current source anymore. So we make it look like a current source by inserting a little extra current from the output of the amplifier as the resistance increases. In this way, we "boot-strap" the current source to make it behave better than it otherwise would. The voltmeter gain is carefully controlled by feedback, and a boot-strap resistor is chosen for each range. It is difficult to get good results on the 100 Megohm range unless the boot-strap resistor is placed somewhere near the middle of the divider string. It is for this reason that the 9 Megohm resistor is made of two 4.5 Megohm resistors.

We have discussed every function except one: the BAT CHK circuit. To check the batteries, the meter, in series with a resistor, is placed across the voltage regulator series pass transistor. The minimum acceptable battery voltage is one that results in 0.8 volts across the series pass element and the meter is set to read 0.2 at this voltage.

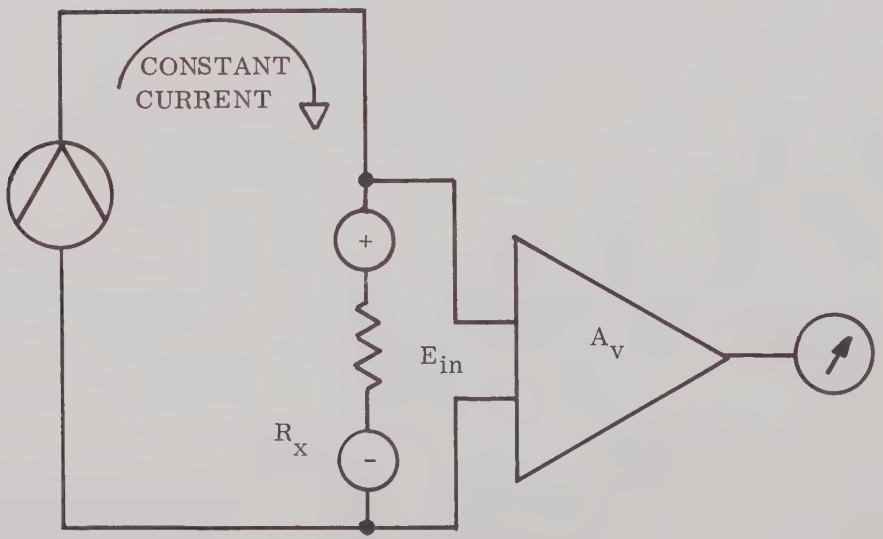


Figure 15A. CONSTANT CURRENT LINEAR OHMS CIRCUIT

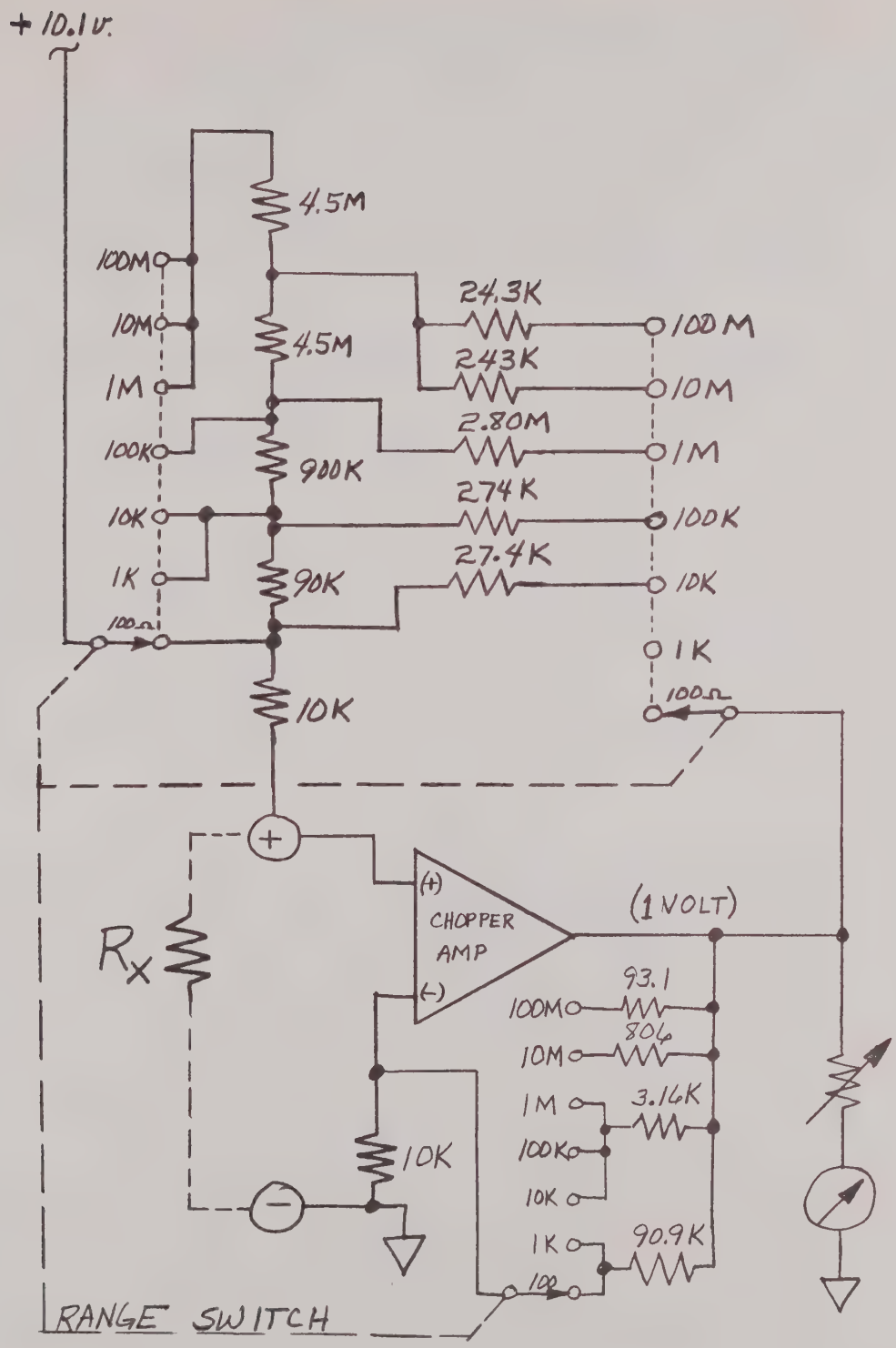


Figure 15B. DIRECT OHMS CONNECTION

IV. DETAILED EXAMINATION OF THE ELECTRONIC CIRCUIT

4-1. The Power Supply/Battery Charger

Referring to Figure 16, the power transformer T2 has a dual primary, allowing the instrument to operate from either 115 VAC or 230 VAC. The transformer secondary has two taps: a center tap for a fullwave rectifier battery charger and an intermediate tap for power to run the instrument from the line.

Lamp DS1 acts as a battery charging ballast, limiting the charge current into a totally dead battery to a non-destructive value while still providing adequate charge current regulation at normal battery voltages. The lamp also provides front-panel indication that the batteries are indeed being charged. This lamp is not installed on throw-away battery versions of the 853A.

Diode CR12 and capacitor C30 form a half-wave rectifier to power the instrument when plugged into the line. This rectified voltage also reverse biases CR13 to prevent battery discharge with line operation and to allow normal operation to continue if the batteries have been severely discharged and are at a very low voltage.

Resistor R63 limits diode surge currents when initially charging C30.

4-2. Voltage Regulator/Reference Supply.

Transistor Q22 is the voltage regulator series pass element (See Figure 16). Resistor R66 provides starting current to initially power up the reference element. The network R75, R76, R77, R78 and R80 form the reference supply Beta String, comparing a portion of the output voltage to a precision reference element. This reference element and the first stage of the comparison amplifier form transistor/zener Q25. These two elements so packaged and operated at an optimized bias level provide a reference voltage with a very low temperature coefficient. From this reference, the 853A derives its measurement stability. Resistor R73 is selected to provide the optimized bias level, and resistor R70 provides additional zener current. Transistors Q23 and Q24 form a differential amplifier, the second stage of the comparison amplifier. Resistors R68 and R69 provide a bias for the differential pair. The output of the differential pair feeds the series pass element Q22 which completes the loop and provides a stable reference voltage.

The Battery Check function is obtained by placing the meter, with a series resistor, across the series pass element, Q22, as indicated by the dashed circuitry in Figure 16.

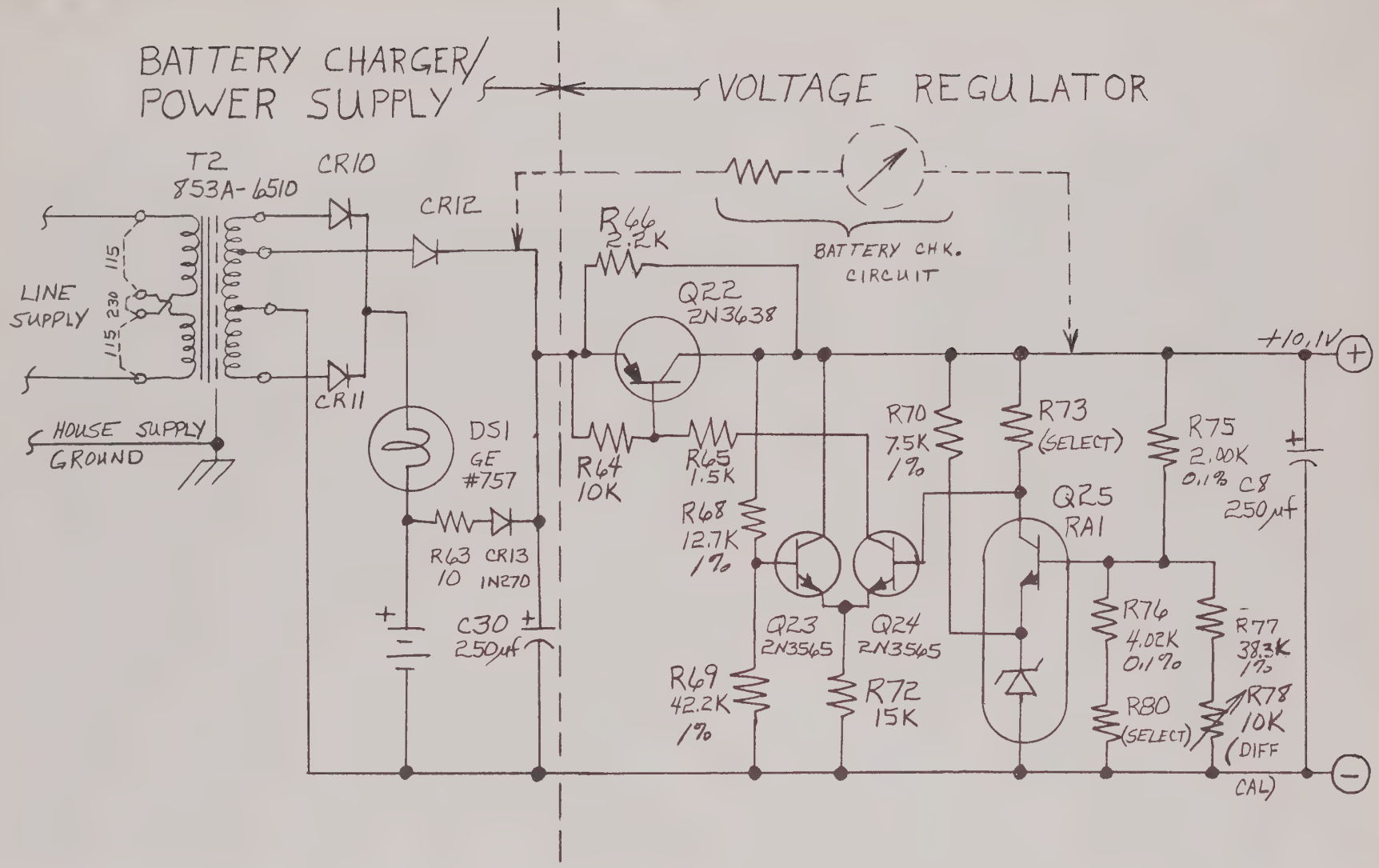


FIG 16. 853A BATTERY CHARGER/POWER SUPPLY AND 10.1 VOLT REFERENCE REGULATOR

4-3. Inverter/Isolator (See Figure 17)

The inverter/isolator generates a squarewave signal at approximately 215 Hz. During the first half of the squarewave cycle (see Figure 18), Q20 is on and saturated, holding half of the primary winding at about +10V (V_A is Figure 18B). The other end of the primary windings (V_E) is driven to about -10V by auto-transformer action. Resistor R56 supplies base current to saturate Q20, and Q20 clamps the V_B end of the timing winding to +10V. Transformer T1 timing winding acts as a 7 volt battery (with polarity as indicated in Figure 18C) and, in series with the charge that capacitor C22 retains from the previous half-cycle, holds Q21 cut off. C22 discharges through R57 and the timing winding, causing V_C to change exponentially toward 0.0V with time constant $t = R57 \cdot C22$. When V_C reaches approximately +10 volts, Q21 begins to turn on, decreasing the voltage on the timing winding. This decreased voltage turns Q20 off a little, causing Q21 to turn on harder. Turning Q21 on harder causes timing winding voltage to decrease still more, driving Q20 further toward cut-off.

This regenerative process continues until Q21 is in full saturation and Q20 is completely cut off, and the timing winding has completely reversed polarity, beginning the second half of the inverter cycle.

The situation in the second half-cycle is represented in Figure 18D. The timing winding again acts as a 7 volt battery in series with capacitor C22, which has a charge of 7 volts (Polarity as shown) retained from the instant before switching into the second half of the cycle. These two voltages add to apply a reverse bias to Q20, holding it off and, except for leakage currents, effectively removing it from the circuit. Now C22 discharges through R56 and the timing winding, causing V_B to approach 0.0 volts exponentially with time constant $t = R56 \cdot C22$. When V_B reaches about 10 volts, Q20 turns on again, turning off Q21 and completing the cycle.

The frequency of the inverter is controlled, as seen in the foregoing discussion, by the charge and discharge of capacitor C22 through R56 and R57, respectively. It does not depend, as most transformer-coupled multivibrators do, on the saturation characteristics of the transformer core, thus yielding uniformity of multivibrator characteristics in production quantities.

The secondary of the transformer is rectified in a positive and a negative half-wave rectifier to supply dc bias voltages for the null detector. Because of the frequency stability and repeatability, the chopper drive (and demodulator drive) may also be derived from the secondary. Transformer coupling allows the null detector power supplies (and, therefore, the null detector) to float relative to the rest of the instrument, thus providing electrical isolation of the null detector from the reference supply. A shield added to the transformer enhances this isolation and prevents capacitive coupling between the circuits.

4-4. Null Detector/Voltmeter

The null detector (Figure 17) is a chopper stabilized dc amplifier. It consists of an input filter, a chopper, an ac coupled carrier amplifier, a synchronous demodulator, an output filter, a meter adjusting network and a chopper drive circuit.

Components R5, C5, C10, R21 and C11 form a low pass filter to minimize common mode noise interference and Q10 provides over-voltage protection for the chopper, acting as a normal diode for positive voltages and as a 7 volt zener for negative over-loads.

Resistor R22 and MOS FET Q11 form the chopper circuit, providing a squarewave output to C12 with amplitude proportional to the difference between the input voltage and the feedback voltage (noted in Figure 17) and frequency equal to that of the inverter, discussed above. When operated as a null detector, the DIFF/DIR (differenital/direct) switch shorts the feedback voltage to ground, making the chopper output proportional only to input voltage.

Capacitor C12 couples the chopper output to the carrier amplifier, consisting of Q12, Q13, Q14, Q15 and associated bias circuitry. Transistors Q12 - Q14 form an emitter coupled negative feedback triplecton, whose gain is roughly proportional to R26/ (R41 + R15). The combination of R41 and R15 is used to vary the gain of the carrier amplifier (and, hence, of the over-all null detector). In DIFF (null detector mode of operation) the front panel control R15 adjusts the sensitivity over a range of 100 to 1; this allows low sensitivity to initially locate the null, then selectively greater sensitivity to obtain a precise reading. In DIR (voltmeter operation) the DIFF/DIR switch shorts out the gain control pot R15, giving the amplifier maximum gain dependent only on R41. The amplifier is then insensitive to front panel manipulation of R15. Resistor R42 provides a return path for bias current of the Q12 - Q14 tripleton, making the amplifier bias insensitive to variations of R15 without requiring a dc blocking capacitor.

Transistor Q15 is simply an inverter, operating with an approximate gain of two. Bias stability for the overall amplifier is obtained by feeding back a portion of its emitter voltage to Q12 via R30, R44 and R45.

The carrier amplifier output is developed across R43 and capacitively coupled to the demodulator transistor of Q16 by C16. The demodulator, driven in synchronism with the chopper via R54, is operated in the inverse mode to secure the minimum saturation voltage and, therefore, the minimum zero-signal off-set.

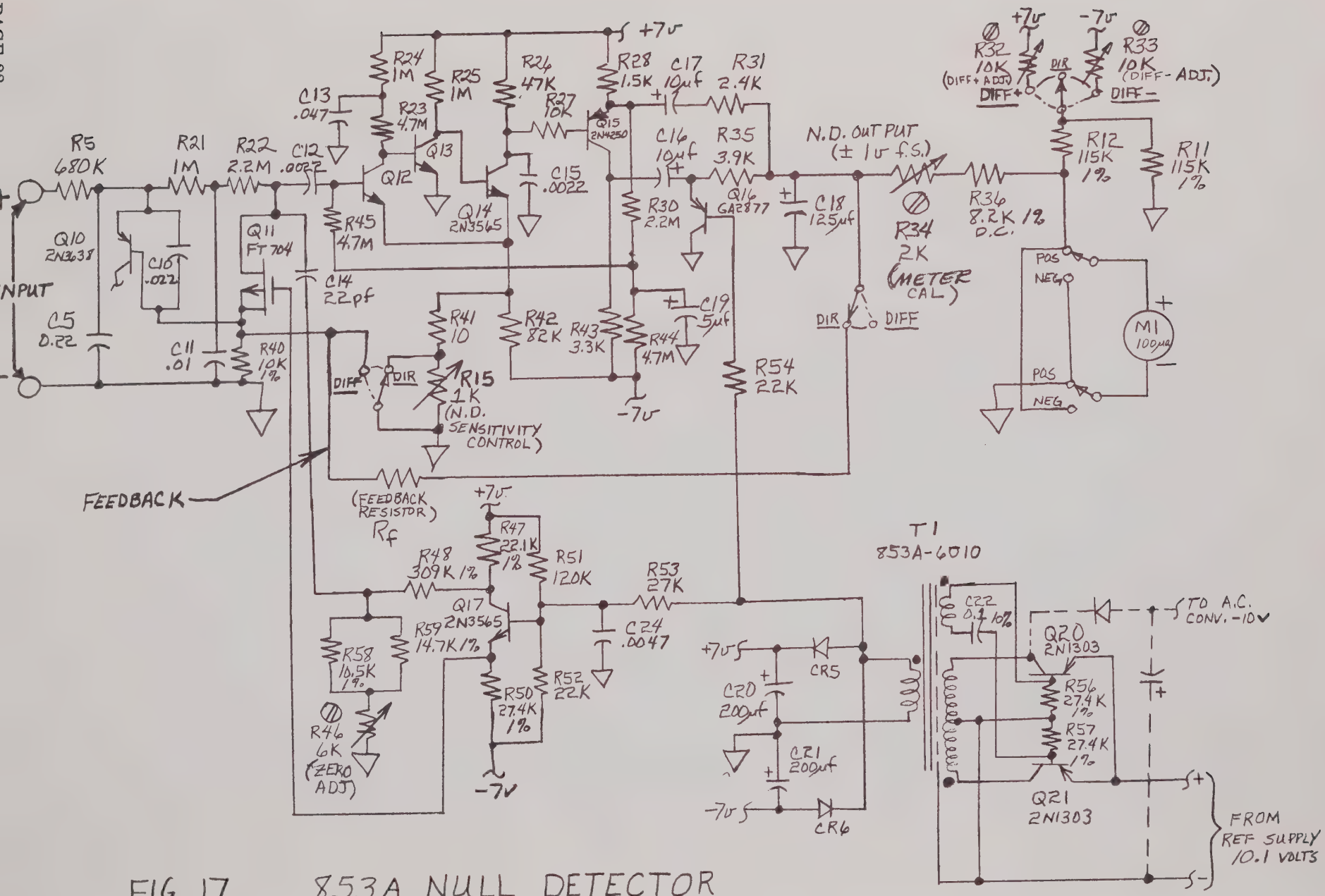
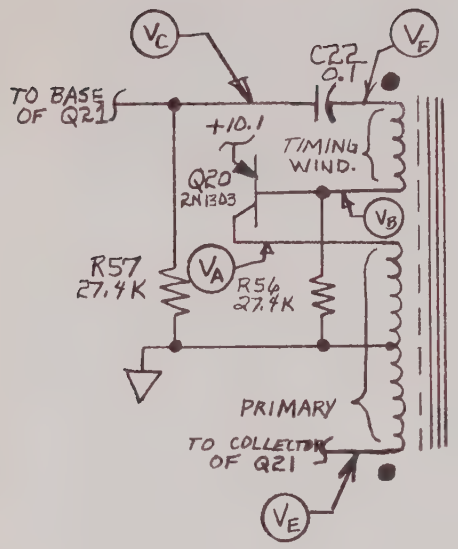
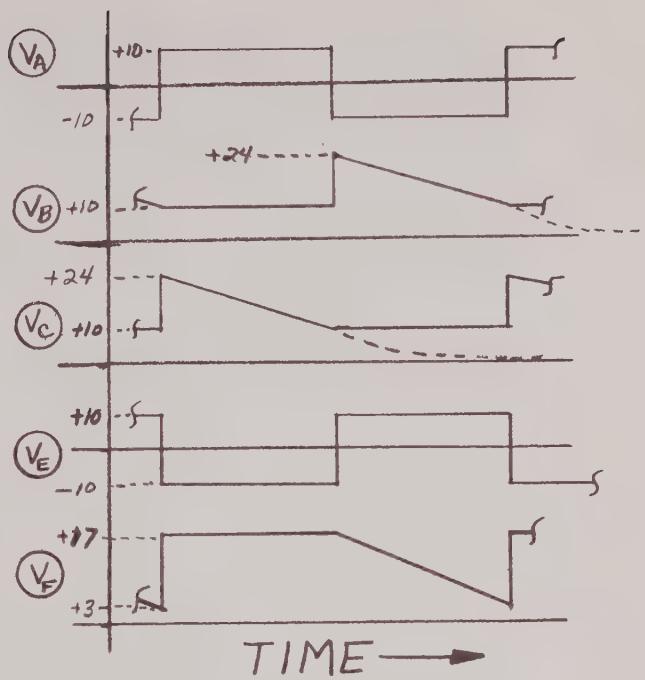


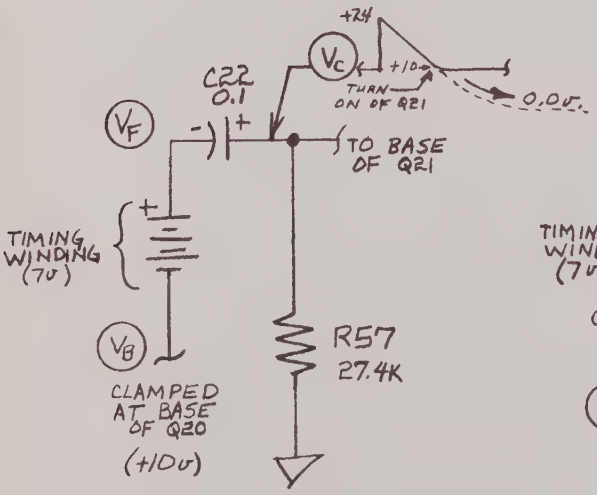
FIG 17. 853A NULL DETECTOR AND INVERTER



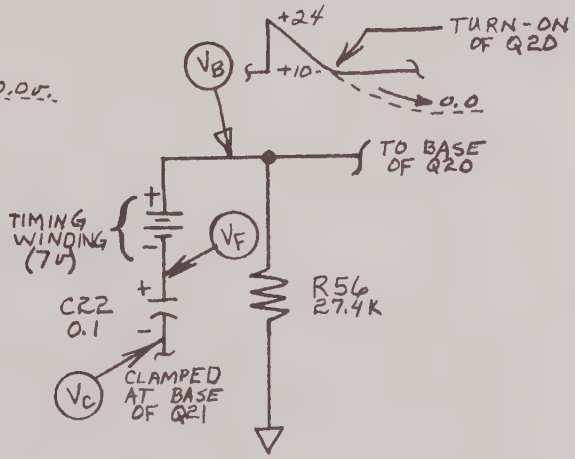
(A) ACTIVE CIRCUIT CONNECTION DURING FIRST HALF CYCLE.



(B) WAVEFORMS



(C) EFFECTIVE TIMING CIRCUIT DURING FIRST HALF CYCLE



(D) EFFECTIVE TIMING CIRCUIT DURING SECOND HALF CYCLE

FIG. 18. INVERTER/ISOLATOR TIMING DETAIL

Resistor R39 and capacitor C18 operate as a low pass output filter, more than adequate if the amplifier served only as a null detector. Since negative feedback must be derived from this signal for DIR operation, any signal at the chopper frequency on this line would be fed directly to the negative feedback input of the null detector and generate an error signal. To adequately reduce the ripple, resistor R31 couples an out-of-phase chopper frequency signal from the emitter of Q15 to the output line to approximately null the ripple remaining after filtering.

A feedback resistor R_f, selected according to the range (VOLTS, CURRENT, OHMS), then completes the loop for DIR operation and sets the null detector output line at ±1 volt full scale.

The meter adjusting network consists of the meter calibration network R34 and R36 and the "center zero" network R11, R12, R32 and R33. Resistor R36 is deposited carbon to compensate for the temperature coefficeint of meter resistance, and R34 calibrates the meter. The "center zero" network supplies approximately 50 ua to spring the needle (normally a zero-left meter) to the center to allow positive and negative meter deflection when operating as a null detector (in DIFF mode).

For positive voltage measurements (DIFF +), R32 adjusts the spring current. For negative voltage measurements, the meter polarity is reversed and in DIFF- operation a negative spring current is required. Because the negative power supply voltage may be slightly different than the positive supply voltage, a asecond pot R33 adjusts the negative spring current. Resistor R11 effectively doubles the range of the adjustments.

The remaining area of interest in the null detector is the chopper drive circuit, consisting of Q17 and associated components. The emitter of Q17 provides a squarewave signal to the MOS FET gate to turn it on and off at the frequency of the inverter. The amplitude of this drive voltage is determined by transformer T1 output, R52, R53 and the base-emitter drop of Q17. Resistor R51 prevents Q17 from completely cutting off on the negative half of the transformer output, and C24 filters transformer noise from the signal in addition to slowing the rise time to reduce the spike amplitude fed through C_{rss} (gate-to-drain capacitance of the MOS FET).

The collector of Q17 generates an out-of-phase signal that precisely tracks the voltage applied to the MOS FET gate. Network R46, R58-R59 nad R48 attenuates this voltage to a level necessary to drive capacitor C14 which accomplishes two things: (1) it nulls the spike induced on the MOS FET drain produced by C_{rss} and the squarewave applied to the gate, and (2) it provides a return path for the current induced by the spike. The precision tracking of the collector signal is required to effectively cancel the spike. But even with this precaution, the voltage variance

of C_{rss} prevents a constant capacitance from exactly cancelling the spike. So we are still left with a small spike, cancelling only the average value of C_{rss}. Because of the broad range of C_{rss} anticipated in purchased MOS FET's, and to obtain adequate resolution of the null detector zero adjustment, R58 and R59 provide three ranges of compensating voltage by selectively removing one or the other (or neither) from the PCB.

4-5. AC-DC Converter (See Figure 19)

The ac-dc converter uses the operational amplifier principle, with gain supplied by a carrier amplifier and controlled by an input resistor and a feedback resistor. The carrier amplifier consists of a three-stage amplifier, Q1 - Q3, a constant current source, Q5, and a dynamic load, Q4. To bias the constant current source, -10 volts in derived from the auto-transformer action of the inverter transformer via half-wave rectifier CR7 and C25. The current from the source supplies Q1 bias and is adjusted to provide current through R8 to set the emitter of Q3 at about +0.88 volts. The mid-band gain of the carrier amplifier is proportional to R8 over R7. C3 determines the upper 3 db cut-off frequency; C2 determines the lower 3 db frequency.

The dynamic load, composed of R4, R5, R6, C4 and Q4, presents a low static resistance and a high dynamic resistance to the output of Q3. This characteristic allows a large bias current to flow with relatively little bias voltage drop. The low bias voltage drop was required because of the low supply voltage available. The high dynamic resistance and the high bias current of the dynamic load give the carrier amplifier the output characteristics of a constant current signal source. This drives the diodes CR1 and CR2 of the fullwave output detector through their cross-over region very rapidly, producing very low cross-over distortion in the signal developed across R18.

The signal developed thus across R18 is the output signal controlled by the operational amplifier-type negative feedback, and causes a current directly proportional to the input voltage to flow through the output detector diodes CR1 and CR2. The dc voltage output is then developed by placing a resistor (R14, R16 and R17) in series with one of the diodes. Since a positive-going voltage is desired, CR2 is selected. Capacitor C6 prevents a large ac voltage being developed on the positive half-cycle; this keeps the output voltage of the carrier amplifier from exceeding its linear range. Thus, R17 calibrates the dc output without changing ac levels involved in producing the dc. R-C filter R15 and A3C5 reduces the ripple to a level that will not interfere with proper null detector operation.

To generate the proper full-scale voltage out of the ac-dc converter, the range switch selects the proper combination of input resistor and feedback resistor. A4R1 is the input resistor for all voltage ranges, and R20 - R21 are the current input. R21 calibrates the ac current range. A3C1 and A2C3 are dc blocking capacitors. A2C1 and A2C5 adjust the high frequency response of the current and 1 volt ranges, respectively. Feedback resistor R22 serves both current and the 1 volt ranges; resistors R23 - R25 serve the remaining voltage ranges.

The remaining feature of interest in the ac-dc converter is R26, the input resistor to the base of Q1. In the current ranges and the one volt range, the feedback summing point sees a large source impedance, the input resistance in parallel with R22. R26 is shorted out in these ranges and the source impedance forms a pole with the input capacitance of Q1; the amplifier is designed to operate stably with this pole. When the lower value feedback resistors are switched in, this pole moves to a higher frequency and in the worst case extremes of component parameters this could cause the amplifier to oscillate. To prevent oscillation, R26 is switched into the circuit to keep the pole at a low frequency.

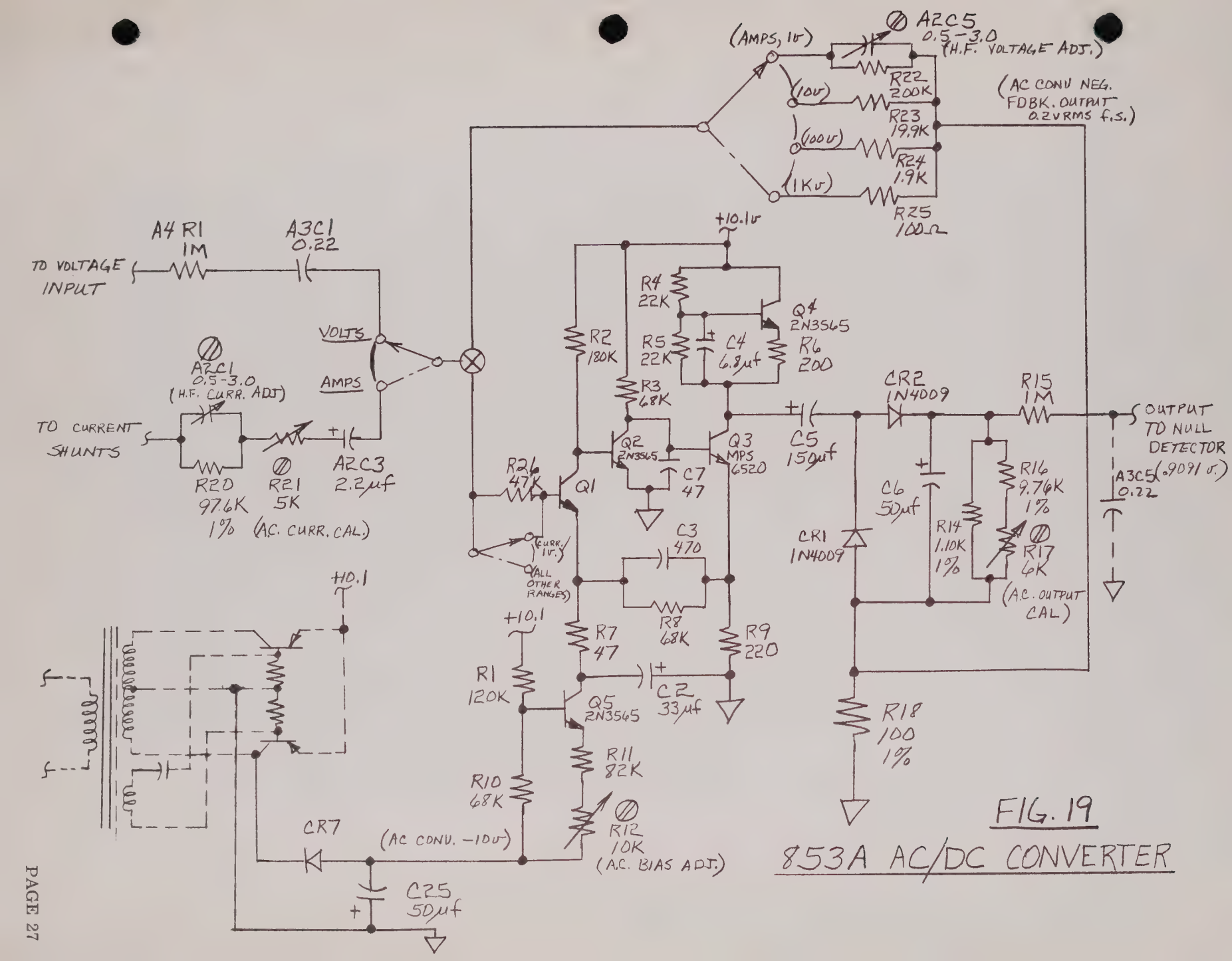


FIG. 19

853A AC/DC CONVERTER

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JOHN FLUKE MFG. CO. INC.
P.O. Box 7428 Seattle, Washington 98133

March 1, 1968

SERVICE BULLETIN CROSS-REFERENCE INDEX

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2	Polarity Offset	825A
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5	Zero Drift	910A
6	Meter Rattle	910A
7	Temperature Compensating Network	408A
8	Random Transient in HV Output	407D
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S.B. #	Subject	Instrument(s)
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22	Relay K1 in Models 313A, 382A, and 383B	313A 382A 383B
23	Null Detector Gain	801B 803B
24	Null Detector Protection	871A 873A
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37	Filament Regulator Kit	800 801 801H 803
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895A	Charge - Discharge Cycles of Ni-Cad Batteries	40
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SAN-DEL
CLEANING SYSTEM

FOR FAST, ECONOMICAL and COMPLETE CLEANING OF

- **Electronic Instruments**
- **TV Cameras and Receivers**
- **FM Tuners**
- **Electric Motors, Relays, etc.**
- **Nuclear Equipment**
- **Typewriters, Adding Machines, etc.**

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MODEL 12 CLEANER WITH STAND

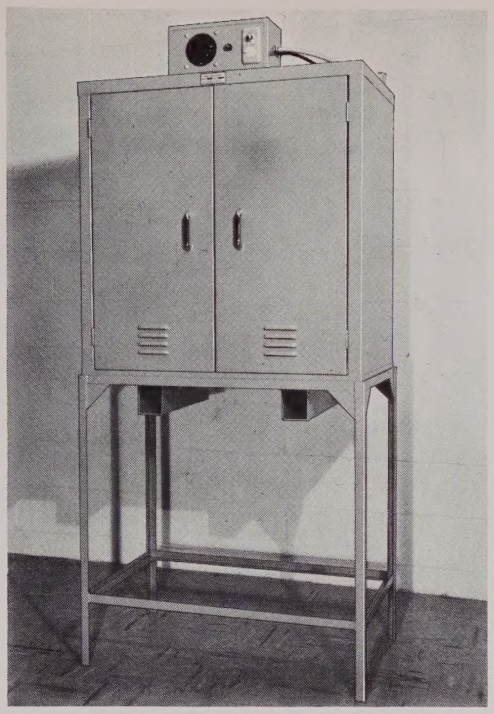
All electronic and electrical equipment will operate better, be more stable and will more nearly meet original specifications if kept clean and free of electrical leakage. It is especially necessary that electrical cleanliness be observed with electronic instruments that are to be calibrated to a high order of accuracy.

The development of the SAN-DEL system was motivated primarily by the need of service and calibration laboratories for equipment to easily and quickly clean electronic instruments. It has been found that clean instruments can be more quickly and economically serviced and will retain their calibration accuracies much longer.

The SAN-DEL Cleaning System cleans electronic instruments by removing contaminating elements such as common laboratory dust, tobacco smoke, oils and residue, industrial smoke residue, oxides, etc.

The system is composed of two pieces of equipment — the Model 12 SAN-DEL Cleaner and the Model 44 SAN-DEL Oven. These units are designed to accommodate equipment of size up to and including the largest cathode ray oscilloscopes, TV chassis complete with picture tubes, and other equipment weighing up to 150 pounds.

The SAN-DEL Cleaner uses the basic principle of cleaning with a special detergent-type cleaning solution. The instrument to be cleaned is placed on the hand-operated turntable of the SAN-DEL Model 12 Cleaner, and the cleaning solution is applied by means of a high pressure gun from a solution tank located in the cleaner. After application of the solution, the instrument is rinsed with tap water, also applied with the high pressure



MODEL 44 OVEN WITH STAND

gun. An air gun is supplied to help remove excess water. The instrument is then transferred to the SAN-DEL Model 44 Oven where it remains until dry.

The Model 12 Cleaner is equipped with turntable, shadowless lighting system, exhaust blower, adjustable air pressure regulator, air gauge, solution tank, solution and air guns. Intake water and drain connections will accept standard hose fittings. The cleaner is equipped with three globe valves for introducing water to the solution tank and for directing the solution and rinse water to the high pressure gun.

We recommend the use of SAN-DEL No. 2 TECHNICAL CLEANER liquid concentrate for electronic and electrical equipment. It is effective for brightening cadmium plated and aluminum parts and for removing oxide tarnishes from open switch and wiper contacts. This cleaner is in no way injurious to electronic components and wiring and is non-toxic. A gallon of SAN-DEL No. 2 TECHNICAL CLEANER concentrate is furnished with each Model 12 Cleaner. This will make six gallons of working solution — enough to clean twelve or more average size instruments.

The Model 44 Oven uses the efficient infrared principle of heating. It is a low temperature oven designed specifically for drying electronic equipment (max. temp. 125° F). The temperature may be increased somewhat, if required, to speed up the drying of equipment such as electric motors that can stand higher temperatures. Temperature of the item being dried is determined by the voltage applied to the infrared lamps. The proper voltage for the temperature desired is set by a control mounted on top of the oven. The oven may be operated continuously and completely unattended with positively no chance of over-heating and exceeding desired temperatures.

SPECIFICATIONS

SAN-DEL CLEANING SYSTEM

SPECIFICATIONS	MODEL 12 CLEANER	MODEL 44 OVEN
Overall Dimensions	32¼" W 32¼" D 46" H	34⅛" W 22" D 46" H
Weight — Net Shipping	190 lbs. 250 lbs.	135 lbs. 190 lbs.
Material	Welded steel, zinc phosphate dipped	Welded steel, zinc phosphate dipped
Finish	Light grey enamel	Light grey enamel
Power	115V - 1ph 60 cycles 350 watts	115V - 1ph 60 cycles 500 watts
Air Source	50 to 200 psi 3½ cfm at 50 psi req'd	
Water	Intake water and drain req'd	
Exhaust	Outside venting recommended. 4"x4" duct flange provided	

Price and Ordering Information

Model 12 Cleaner (stand not included) $925.00
Model 44 Oven (stand not included) $565.00
Stand for Cleaner . . . . . $ 62.50
Stand for Oven . . . . . $ 60.00
SAN-DEL No. 2 TECHNICAL CLEANER (1 gal. container) . . $ 5.50
SAN-DEL No. 2 TECHNICAL CLEANER (4 gal. carton) . . . . . $ 20.50

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